Exploring Integration Methods for Multiple Statewide Hydrography Datasets in Minnesota

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Authors

Lyn Bergquist – Minnesota Department of Natural Resources (DNR)
Jim Krumrie – Minnesota Geospatial Information Office (MnGeo)
Sandi Kuitunen – MnGeo
Susanne Maeder – MnGeo

Reviewers

Jennifer Crea – Minnesota Pollution Control Agency (MPCA)
John Hoshal – MnGeo
Steve Kloiber – DNR
Tim Loesch – DNR
Tom McCann – United States Forest Service (USFS)
Joe Miller – USFS
David Morley – USFS
Mark Olsen – MPCA
Kris Parson – MPCA
Glenn Radde – DNR
Dan Ross – MnGeo
Chris Sanocki – United States Geological Survey (USGS)
Jamie Schulz – DNR
Joel Skalet – USGS
Glenn Skuta – MPCA
Sean Vaughn – DNR
Ron Wencl – USGS

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Abstract

This project was undertaken to determine the feasibility of integrating the **MN National Hydrography Dataset (NHD)** and the **MN DNR Enterprise Hydrography Dataset** into a single, statewide geospatial dataset that meets the diverse business needs of Minnesota's user community. By integrating the state's geospatial hydrography data into a single authoritative dataset, the hope is to eliminate redundancy in effort, improve efficiency of updating and reporting, and foster easier data sharing and collaboration among its many users.

Integration is a two-step process that involves: 1) initial statewide synchronization of the two datasets and 2) a long-term maintenance strategy to keep them synchronized. Under the scope of the NEIEN 2008 grant, the project team sought to first quantify the current differences between the MN NHD and DNR Hydrography Datasets. Tools and procedures were tested to bring them into complete synchronization at the statewide level. Then the project team designed and tested three different model options for maintaining synchronization over the long-term, either by integration within a single dataset or through maintenance of parallel datasets via "lagged synchronization". Pilot testing led to a discussion of the benefits, limitations and costs of each option. Finally, a recommended maintenance option was agreed upon for further consideration.

This document outlines the history, the current status and the proposed future of the statewide spatial hydrography dataset(s) for Minnesota. It fully discusses the technical details of synchronization and long-term maintenance, and offer estimates of the staff and equipment resources needed for each. This Executive Summary summarizes important aspects of each of the main chapters; much more detail is available within the individual chapters, related appendices and reference materials.

Introduction

The state of Minnesota currently uses two distinct spatial datasets representing the state's surface water hydrography. One is the **MN DNR Enterprise Hydrography Dataset** maintained by the Minnesota Department of Natural Resources (DNR); the other is the **National Hydrography Dataset (NHD) in Minnesota**, developed by the United States Geological Survey (USGS) and state partners and maintained by USGS with state assistance through its stewardship process. Each dataset has unique characteristics that were developed to meet the business needs of the organizations that rely on the information. Some agencies have a business requirement to use one dataset over the other. Others have a historical familiarity with one dataset, while still others find that neither dataset contains the features necessary to fully represent Minnesota's hydrographic resources. Users are often confused as to why there are two datasets, why the features and attributes differ, and how to choose the dataset to best meet their business needs. Agencies maintain these datasets separately and need to cross-reference their data to different systems, resulting in challenges for data sharing and a duplication of efforts. These problems would be solved with a single, centralized "best features" hydrography dataset.

History

Surface Hydrography Features

DNR geospatial data representing surface water hydrography has a long history. The original source of DNR linear streams data was the Minnesota Department of Transportation 1:24,000 (MNDOT 24K) Basemap dataset, automated in the 1990's. Also in the 1990's, lake polygons became available from two sources: the USGS 1:100,000 Digital Line Graph (DLG 100K) dataset and the DNR 1:24,000 (DNR 24K) Lakes dataset derived from the National Wetlands Inventory. The DNR 24K Lakes and DNR 24K Streams datasets were intersected and attributed to become DNR's first spatially-integrated hydrography dataset.

In 1993, the medium-resolution (1:100,000 scale or 100K) National Hydrography Dataset was jointly developed by the USGS and the U.S. Environmental Protection Agency (EPA) with the goal of producing a nationwide geospatial dataset of surface hydrography features. After the year 2000, the agencies pursued development of a high-resolution (1:24,000 scale or 24K) version of NHD using lake and stream delineations as depicted on USGS 1:24,000 base maps. Due to the amount of work involved, the 24K NHD was intended to be a collaborative effort between many agencies (i.e., federal, state and local).

From 2002-2005, the high-resolution NHD for Minnesota was constructed using the DNR 24K Streams, DNR 24K Lakes and DNR 24K River polygons to build NHD Flowlines, NHD Waterbodies and NHD Area features, respectively. The recommendation to use DNR data was made with the assumption that it would be easier to keep the two datasets synchronized if they shared common base features. The result was that the initial high-resolution NHD and DNR hydrography data were very similar, if not coincident, throughout most of the state. However, ensuing data enhancements in the coming years would serve to undo the synchronization.

Following its completion in 2005, the MN NHD was subsequently updated by the USGS during many "maintenance cycles". Updates included global improvements to topology (i.e., geospatial relationships between features), image alignment of larger features to aerial photos and the addition of water feature names from the USGS Geographic Names Information System (GNIS). In addition, the Twin Cities Metropolitan Council (Met Council) added storm water features and the Minnesota Geospatial

Information Office (MnGeo) performed general updates to improve feature naming, delineations and stream networks.

During this same time period, the DNR integrated hydrography data underwent extensive editing and enhancement. DNR added legally designated trout streams and attribution to the linear stream features, and created a new Public Water (PW) basins and watercourse feature classes for regulatory mapping. Many stream and open water features were re-digitized to better match current aerial imagery. In 2012, the "best available features" from multiple existing layers were combined to form the new enterprise DNR Hydrography Dataset, effectively replacing the 24K and 100K DNR legacy datasets for state surficial hydrography.

Consequently, over the 10-15 years since the high-resolution MN NHD was created using DNR legacy data, the separately maintained datasets have diverged significantly. Despite well-intentioned efforts to track and coordinate updates to both, the NHD and DNR datasets have gradually become unsynchronized.

Watershed Boundaries

Watershed mapping and geospatial data development has a history parallel to that of the stream and lake hydrography. The DNR *Watershed Mapping Project* (1979) was the first attempt to delineate and automate height-of-land boundary maps for all watersheds in Minnesota, and resulted in the original 81 "DNR Major Watersheds" and 5600-plus "DNR Minor Watersheds". The original 81 Major Watershed boundaries were a refinement of a 1970's federal watershed mapping effort.

The DNR Lake Watershed Delineation Project, beginning in 1998, improved upon the original effort while using GIS technology. The main intention was to delineate watersheds for all lakes with a surface area of 100 acres or greater (about 4000 lakes). A further benefit of this project was an update of the DNR Major and Minor Watershed Boundaries. The end result of the 1998 project was the development of the DNR "Catchments" dataset, a set of smaller drainage unit "building blocks" that can be aggregated to create larger drainage areas such as the DNR Major and Minor Watersheds.

Beginning in 2000, the USGS, working with the Natural Resources Conservation Service (NRCS), helped to develop the nation's Watershed Boundary Dataset (WBD), drawing upon the experience of hydrologic unit mapping work completed by both agencies in earlier decades. The WBD was incorporated into NHD in 2011 as the new "Hydrologic Units" component. The WBD consists of a set of nested "Hydrologic Units", where the smallest units (called HUC-12's) are aggregated to create larger drainage areas (up to the largest units, HUC-2's). Minnesota's HUC-12s, in turn, are aggregated from the DNR Catchments. Thus, as DNR Hydrography datasets are the foundation of a high-resolution NHD for Minnesota, DNR-developed watershed data is the foundation for Minnesota's WBD..

Business Needs of the Selected Agencies

Before integration of the NHD and DNR Hydrography Dataset is possible, the business needs of each of the stakeholder agencies must first be understood. Over time, the two datasets have evolved separately to meet a specific set of different business needs. Integration can be considered viable only if all of the various agency business needs are adequately met.

DNR

By definition, the DNR is the principal Minnesota executive branch agency responsible for natural resource management. The DNR has numerous statutory and programmatic responsibilities for assessing and managing Minnesota's waters to benefit the state's diverse plants, fish, wildlife and human populations (*Appendices 2a-c*). A specific Minnesota statute (*M.S. 103A.401*) outlines the DNR's responsibility to maintain a S*tatewide Water Information System*, of which geospatial surface hydrography data is a vital component.

To support these responsibilities, the DNR collects large amounts of water-related data. In many cases this data must be referenced to geospatial data layers in order to analyze and report on Minnesota's aquatic resources. DNR staff generate numerous derived geospatial data layers that feed the DNR Geospatial Data Resource Site (GDRS), Minnesota Geospatial Commons web portal, and web applications such as DNR LakeFinder and Minnesota DNR's Permitting and Reporting System (MPARS). Additional uses include watershed-related planning and research, conservation targeting, public recreation mapping, fish and wildlife habitat management, sustainable water use planning and enforcement of the Wetlands Conservation Act.

In general, DNR requires accurate delineations of surface water hydrographic features including lakes and open water, public waters, wetlands, streams, rivers, ditches, watersheds and hydrologic points of interest. Features must be spatially integrated with each other in a comprehensive, statewide dataset. In addition, features must have accurate and consistent characteristics as reflected via attributes (e.g., unique IDs, waterbody names, wetland types, stream types, etc.)

DNR maintains its own set of highly specialized geospatial hydrography features called the DNR Hydrography Dataset. This dataset was designed to serve DNR's diverse and specialized business needs related to conservation, management and regulation. It has a long history and is widely recognized as a foundational geospatial hydrography dataset for Minnesota. Unlike MPCA and USFS, DNR does not have a regulatory or federally-mandated business need for NHD at this time. In fact, NHD (in its current state) does not have sufficient features or attributes necessary to meet these unique business needs.

MPCA, USFS, USGS

Other agencies, both state and federal, rely upon spatial hydrography data due to their business needs. The MPCA has delegated authority from the U.S. Environmental Protection Agency (EPA) to carry out provisions of the federal Clean Water Act (1972) with its own monitoring, assistance and enforcement programs. In addition, MPCA manages and executes many state-initiated water quality monitoring programs. To support its mission, the MPCA collects water quality data related to streams, lakes and watersheds and stores them as "events" referenced to NHD stream routes or waterbodies. The EPA requires that NHD be used for implementing the Clean Water Act because of its nationwide coverage. The dataset meets most of MPCA's needs for positional accuracy, currency, feature content, topological accuracy and scale correctness. However, since MPCA collaborates with DNR extensively on water-related issues, the fact that the two agencies use different base geospatial hydrography datasets makes data coordination more difficult.

The USFS, as the management authority for the national forests and grasslands, requires accurate hydrography data for its planning and administrative roles. NHD is used in conjunction with watershed improvement and aquatic resources data as well as in updating Forest Service topographic and visitor maps. While some national forests currently have their own individual hydrography datasets, the USFS is working to move them all to NHD. USFS Region 9, of which Minnesota is a part, has officially adopted NHD and WBD as its working hydrography and watershed data. (Members of the Minnesota USFS are eager to incorporate new edits into NHD in time for their Forest Plan revision work in FY 2016.)

Since USGS is one of NHD's original developers, the hydrography dataset retains primary importance to the agency. One of the USGS's central missions is to collect and disseminate information needed to understand the nation's water resources. NHD was created to support this mission by helping to produce hydrography and hydrology data and to enable mapping and analysis. More specifically, this includes producing data about stream flow, water use and quality, as well as providing flood mapping and watershed modeling capabilities. The USGS relies on federal, state, tribal and local partners to input local knowledge within the guidance of its national NHD framework. In turn, the USGS, working under the guidance of the NHD Management Team (consisting of state and federal partners) provides coordination, data management, tools and quality control.

All Agency Watershed Needs

The DNR uses its smallest watershed unit, the DNR Level 08 Catchments, to create its lake watershed boundaries as well as its major and minor watersheds. In addition, these catchments are used to build the WBD HUC-12s which, in turn, are used to build HUC-10s and so on. While DNR may mainly use its own watersheds, the fact that DNR catchments are used to derive WBD watersheds used by other agencies like MPCA, USFS and USGS means that DNR catchments are important to everyone in Minnesota. Changes in catchments need to propagate up the watershed hierarchy so that these datasets remain synchronized.

Comparing NHD and the DNR Hydrography Dataset

Quantifying Differences

Prior to recommending a solution to integrating the NHD and DNR datasets, it is essential to quantify and evaluate the extent of their differences. To facilitate this, four HUC-8s were selected to represent the hydrographic diversity of the state, and the geospatial and attribute data within them were systematically compared. Specifically for watercourses, an iterative test was designed that added concentric buffers to the stream line features of both the NHD and DNR datasets. Using these buffers, the test measured the lateral distances between those pairs of lines that represented the same watercourse in the two datasets. Waterbody features were compared by overlaying NHD and DNR lake polygons and measuring their overlapping area versus their total lake area (*Chapter3*). Some important findings were as follows:

- Due to different coordinate systems, the un-projected NHD dataset first had to be projected to match the DNR projection (i.e., UTM, NAD1983, Zone 15). When this was done, rounding errors led to zero features being 100% coincident (i.e., exactly the same in size, shape and location) between the two datasets. Therefore, routine GIS functions that are normally used to identify "identical" features didn't work (e.g*., Select by Location – Features that are Identical*).

- Yet, despite coming from two different coordinate systems, the lateral distances between 93% of paired stream lines from the two datasets were less than one foot in three of the four selected watersheds. These distances were considered to be insignificant as most stream features in the state are at least several feet wide.

- Further, breaking down the lateral distances by stream type showed that, in many cases, those stream line pairs with the largest distances were so-called "artificial paths" or "interpreted connectors" which, by definition, are somewhat arbitrarily digitized. These stream lines were added to both datasets to maintain the connectivity of the overall stream flow network (e.g., water flow through a wetland or a two-dimensional stream feature) and did not actually delineate a visible watercourse.

- Not surprisingly, DNR and NHD open water polygons were much more dissimilar than the stream lines (i.e., just 39% of open water polygons overlapped between datasets). This is a result of the extensive editing that has taken place in the DNR 24K Lakes dataset.

In addition to these findings, planned updates to the DNR hydrography data due to the arrival of new 2014 NWI and LiDAR data are expected to produce even greater differences with NHD hydrographic data than indicated here. Such updates may also impact the synchronization plans of these two datasets as described in the following section.

Synchronizing DNR and NHD Hydrography and Watershed Data

As previously noted, integration is a two-step process. The first step is a one-time synchronization of the two datasets; the second step is a long-term maintenance strategy designed to keep them synchronized in the future.

Initial Synchronization

The first synchronization requires specialized **NHD Conflation tools** developed by the USGS for large, en-masse NHD feature replacement. These tools essentially supplant existing NHD geometry with features from another dataset such as the DNR's while retaining many of the existing NHD attributes. While this procedure sounds simple in concept, in practice it can be quite complicated.

The NHD Conflation Tools require the input (DNR) features to comply with NHD spatial and attribute specifications. For example, stream lines must have node points at their confluences and streams passing through waterbody polygons need to be coded as "artificial paths". While the DNR data meets some of these specifications already, in most cases the input data will need to be further processed (possibly significantly) to fit the NHD model.

It was originally assumed that, due to extensive editing, the DNR dataset always had more correct representations of surface water than NHD. However, a pilot conflation test in 2009 (*Chapter 5*) and further data comparisons in 2010 revealed several areas where NHD had better features. Therefore, features will have to be compared and scrutinized in relation to other reference layers (e.g., latest aerial photography, LiDAR) to determine which features to use in any given area. Feature replacements may need to occur in both directions (i.e., DNR to NHD and NHD to DNR) to properly synchronize the datasets.

The initial synchronization is expected to be a large effort. Despite these potential difficulties, this process should be feasible given adequate resources. A process and a resource estimate to achieve full statewide synchronization of the NHD and DNR Hydrography Dataset is provided in *Chapter 4*.

Synchronizing Watershed Data

Those in the hydrography community of the state recognize that, even though state organizations need watershed delineations at a fine level of detail (like the DNR Catchments), these state delineations should nest within the larger federal delineations so that they can be used as the local building blocks and feed improvements to the delineations in the federal database. Often state reporting is done at the HUC-10 or HUC-8 (DNR Major Watershed) level, and having two slightly different geographic variants of the same named unit is unacceptable.

The DNR Catchments dataset has been used to generate the published version of the WBD. As related in Chapter 10, efforts to bring together these two datasets occurred over nearly a decade as the federal mapping standards and the WBD were being developed. To aid in this, DNR used the federal mapping guidelines to assign Catchments with HUC-10 and HUC-12 codes as the Catchments were being developed. As part of this project, the two datasets were completely synchronized as of August, 2011. This effort was led by USGS-Minnesota, with DNR providing consultation.

Long-term Maintenance

Once the hydrography data is synchronized at the statewide level, subsequent "maintenance" synchronizations should be easier to execute as they will involve far fewer features. However, any viable option for maintaining a single, authoritative hydrography dataset for Minnesota must fully meet the business needs of each partner agency. A strong **Data Governance** plan will help to ensure the long-term sustainability of a multi-editor, statewide dataset (*Chapter 6*). A successful governance plan will include effective interagency coordination and communication (*Appendix 7a*). Dedicated NHD "Stewardship" (a concept that refers to formal co-management of the NHD dataset by USGS and authorized state "stewards") is also necessary (*Appendix 7b*).

In addition to the above considerations, the following technical components are considered essential for any maintenance process:

Essential Maintenance Components

1) **Multiple Editor Environment**
   At least three state agencies (MnGeo, MPCA and USFS) have expressed interest in being able to edit and update NHD features to address their business needs and to improve the state hydrography dataset as a whole. A fourth agency (DNR) maintains its own enterprise spatial hydrography dataset but is interested in synchronizing it with NHD if feasible. External (non-partner) editors may want to submit enhanced data for incorporation into NHD also. All of these potential editors need to have the ability to make the necessary edits to meet their business needs.

2) **DNR Event Referencing**
   DNR staff have developed numerous data layers representing different groupings of hydrography features to support its business needs. To fully meet DNR business needs, any maintenance option must result in derived GIS products that match those currently being produced. Furthermore, DNR wants to retain control over the storage and maintenance of its statutorily-mandated data.

3) **Pre-notification of Intended Edits**
   In order to prevent data editing conflicts and duplication of efforts, a *pre-notification* strategy must be established so that editors can notify partners of intended editing work.

4) **Review, Conflict Detection and Approval of Proposed Edits**
   An essential component of any maintenance option is the ability of coordinating partners to review, resolve and approve edits proposed by other partners. Each partner must signify approval of proposed edits so that core feature classes continue to meet agency business needs, and so that edits made by one partner are not "undone" or in conflict with edits made by another.

5) **Updates to the MN State NHD Dataset**
   After feature edits have been approved by all partners, they must be incorporated into the MN NHD state dataset that resides on the state GDRS.

6) **Updates to the USGS Federal NHD Dataset**
   After feature edits have been approved by all partners, they must be incorporated into the USGS federal NHD dataset.

Three Maintenance Options

The project team tested three principal options for the long-term maintenance of Minnesota's spatial hydrography data (*Chapters 6 & 7*). Each option allowed testing of different strategies to address the above essential components. Because the components are the same among all options, some interchangeability among the technical strategies is possible. The three tested maintenance options are described below:

Maintenance Option #1: Direct editing to a central SDE MN hydrography dataset

Under Option #1, state agency partners (MnGeo, MPCA, USFS and DNR) edit directly to agency-specific versions of NHD within a centralized ArcGIS Spatial Database Engine (SDE) database. SDE versioning, as well as topology tools and rules, are used to achieve feature synchronization and detect conflicts between edits. A customized *pre-notification-review-conflict resolution-approval* process is used to promote agreement of proposed edits among all partners. A State NHD Administrative Steward reconciles approved edits into the state NHD dataset and uses established NHD procedures to update the USGS federal NHD dataset.

Maintenance Option #2: Direct-editing to the USGS (federal) NHD

Under Option #2, state agency partners reference their business data as events directly to the state MN NHD (in the GDRS). Partners use a shared web application such as ArcGIS Online (AGOL) to share, review and approve edits proposed by other partners. Agency partners are trained and authorized as NHD "sub-Stewards" to make edits directly to the USGS federal NHD via the established NHD Stewardship check-out/check-in procedures. The MN State Administrative Steward incorporates the updated USGS federal NHD dataset into the GDRS as the new MN NHD dataset.

Maintenance Option #3: DNR Business-focused editing

Under Option #3, the DNR maintains its existing enterprise DNR Hydrography Dataset to meet specific business needs. DNR continues to reference its data to DNR hydrography base layers using current procedures. However, edits flow in two directions (i.e., from DNR to NHD and from NHD to DNR) in order to keep DNR enterprise datasets synchronized with NHD. The other non-DNR partners edit directly to the USGS federal NHD dataset as described in Option 2.

This table summarizes the specific technical strategies used for each component within each Maintenance Option.

Options:	**OPTION 1**	**OPTION 2**	**OPTION 3**
	Direct Editing in SDE	Direct Editing to Federal	Business-Focused (DNR only)
Components:	(DNR, MNGEO, MPCA, USFS)	(DNR, MNGEO, MPCA, USFS)	(MNGEO, MPCA, USGS) & (DNR)
1. Multiple Editor Environment	MN NHD in ArcSDE; partner-specific "EDIT" versions of NHD	All partners edit individual MN NHD (GDRS copies)	Non-DNR partners edit individual MN NHD (GDRS copies); DNR edits DNR Hydrography Dataset
2. DNR Data Referencing	To base layers derived from reconciled MN NHD	To NHD GDRS dataset as events	To DNR Hydrography Dataset features (current system)
3. Pre-notification	Email, shapefile, ArcMap bookmarks	Shared web app with mark-up (e.g., ArcGIS Online-AGOL)	Shared web app with mark-up (e.g., ArcGIS Online-AGOL)
PROPOSED EDITS			
4a. Review	ArcMap display of SDE versions and reference layers; edit flags and dates on proposed features; via WebEx/Lync or shapefile	Shared web app with mark-up (e.g., ArcGIS Online-AGOL); Editor uploads edits to AGOL; posts Notes, Comments, dates	Shared web app with mark-up (e.g., ArcGIS Online-AGOL); Editor uploads edits to AGOL; posts Notes, Comments, dates
4b. Conflict Detection	SDE Versioning (reconcile/post); Map or Geodatabase Topology; Data Comparison tools; topologic editing tools	Visual review in AGOL; partner Comment and Edit capabilities	Visual review in AGOL; partner Comment and Edit capabilities
4c. Approval	Partners enter names, approval dates, comments into "edit-tracking" table	Partners enter names, approval dates, comments into "edit-tracking" table or notes (AGOL)	Partners enter names, approval dates, comments into "edit-tracking" table or notes (AGOL)
STATE & FEDERAL UPDATES			
5. Incorporating approved edits into MN State NHD	State Administrative Steward copies reconciled MN "default" SDE version to GDRS	State Administrative Steward copies updated federal NHD to GDRS (*after step 6, below*)	**DNR:** passes edits to State Administrative Steward **Non-DNR partners:** State Administrative Steward copies updated federal NHD to GDRS (*after step 6, below*)
6. Incorporating approved edits into USGS federal NHD	State Administrative Steward updates federal NHD using reconciled MN "default" SDE version) AND posts federal updates to state NHD (two-way updating)	State sub-Stewards (all partners) make direct updates to federal NHD from "approved" edits	**DNR:** State Administrative Steward make direct updates to federal NHD from "approved" DNR edits; DNR periodically updates DNR Hydrography Dataset using GDRS NHD **Non-DNR partners:** State sub-Stewards make direct updates to federal NHD from "approved" edits

Table 6-1. Three maintenance options and their component strategies

Maintenance Option Testing and Results

The technical strategies in each option were tested to determine their feasibility (*Chapter 7*).

In Option 1, an ArcGIS SDE geodatabase was set up with remote access so that DNR and MnGeo testers could make edits to partner-specific "edit-versions" within the centralized dataset. *ArcGIS Workflow Manager* was considered as a possible solution for managing *the pre-notification-review-conflict detection-approval* process.

For Options 2 and 3, a mock ArcGIS Online (AGOL) shared web application was set up in which DNR and USFS testers could mark up with comments as well as submit their own "proposed edits" for partner review and approval.

At the end of testing, all of the component strategies tested were found to be "feasible" to varying degrees. Each option had specific benefits, limitations and costs associated with them. Estimates of the resources needed for each option were determined and a recommendation was formed based on subjective weighing of the costs vs. the benefits.

This project was also tasked with investigating event handling as currently practiced by DNR and by the NHD User Community, and identifying ways to improve the capability to exchange and share events. Events are features indexed to a line network like houses are indexed (or addressed) to a road network. The roads are the *routes* that provide the context for indexing the houses (i.e., road numbers and names). In hydrography, the stream line network takes the place of the road network and stream *segments* are the routes. Examples of point hydrographic events include stream gages, dams and water quality monitoring stations. Examples of linear hydrographic events include stream survey reach segments, stream habitat improvement areas, trout stream designations and stream water quality assessment areas. Hydrographic features are indexed to the stream network by designating a measure on the route.

Testing proved that it is feasible to import an event dataset created on one set of stream delineations (e.g., DNR stream routes) to another (i.e., NHD flowlines). The more closely the two data sets match, the more accurate the event transfer. Selection of a tolerance value is important. Unless the two stream delineations are coincident, some review of the data transfer results will always be necessary. The Department of Natural Resources further tested the capability to derive most DNR streams layers as events on the NHD. Their testing proved that it was possible to do so for streams, but not for Public Waters basins (which are regulatory features based on a statutory definition).

A Recommendation for Minnesota Hydrography Dataset Maintenance

None of the three options was determined to be the best solution in its entirety. Instead the most "favorable" component strategies from several options were combined to derive a unique solution for recommendation. This solution includes the following:

1. ***Multiple Editor Environment****: All partners use the state MN NHD (from GDRS) as their base hydrography dataset (Option 2)*

   Reasons: Having all partners use the same base dataset ensures that everyone is using the proper "approved" features. This is a much simpler option than using SDE, which requires administrative oversight and frequent reconciliation of partner versions with the default.

2. ***DNR Event Referencing****: DNR uses linear referencing to spatially index its two <u>core</u> data layers (for streams and open water only) as events to the NHD feature classes and generates its derived products from these core layers using existing processes (Option 1)*

   Reasons: By referencing its core data layers for streams and open water to NHD, DNR ensures that its core features match those that all state partners are using. However, keeping its derived product data referenced as events to these core layers (rather than directly to NHD) simplifies data management. DNR can continue to use its current processes to generate derived products without substantially changing business practices. DNR also retains more control over its event data and can schedule the release of updated derived products rather than having to migrate events as soon as the NHD features change. DNR can take advantage of the USGS HEM Tools for referencing both stream routes and open water polygons (core data) to NHD. (Unlike standard ArcGIS tools, HEM allows the referencing of polygon events to NHD waterbody features.)

3. ***Pre-notification of Intended Edits:*** *All partners use a shared web application such as ArcGIS Online to pre-notify other partners of intended edits* (Options 2 & 3)

   Reasons: ArcGIS Online (AGOL) is a relatively new technology that is rapidly becoming familiar to mainstream users. Because the *review-conflict detection-approval* process is so essential to creating products that meet the business needs of all partners, an easy solution is strongly desired. In testing, AGOL proved to be an easily-to-develop, user-friendly solution for pre-notification of partner proposed edits. Mark-up tools allow partners to easily delineate areas for intended editing. Other partners can review and comment on these intended edit areas and coordinate their edits if desired. (*Note:* other shared web applications with similar functionality may be substituted for AGOL.)

4. ***Review, Conflict Detection, Approval of Proposed Edits****: All partners use a shared web application such as ArcGIS Online to review, detect conflicts and approve proposed edits* (Option 2)

   Reasons: AGOL is a simple collaborative tool for reviewing partner-proposed edits. Partners can upload proposed features into a "provisional edits" review area. Conflict detection is handled by a visual review of all layers made available to the AGOL service. Reviewers can add comments and mark their approval by entering their names and approval dates into "edit tracking" tables or notes. The use of customized web services may allow partners to upload features into a "provisional edits" geodatabase for long-term storage, providing a historical archive of past proposed and approved features.

AGOL can readily be made available to more partners and external reviewers. Non-partners may be allowed to submit (i.e., upload) improved features for potential incorporation into NHD, thus continuing to improve the statewide NHD dataset. To the degree that all users find the features they need in the state NHD, the more comfortable they will be in relying on NHD as their base hydrography dataset.

In comparison with SDE, AGOL requires much less administrative overhead and necessary skill-level. Although SDE versioning offers a multiple-editor environment, the knowledge base required to use it is much greater than AGOL. Managing the versioning, reconciliation and post operations can be confusing and complicated; AGOL is much more user-friendly and flexible. It would be easier to expand the AGOL application and add new users without extensive training.

Although *ArcGIS Workflow Manager* may be a useful option for managing workflow, it is also somewhat complicated. While it wasn't specifically tested here, it may be possible to set up Workflow Manager in the future to communicate with the AGOL web application. DNR will be doing some internal testing to determine the possibilities.

5. ***Updates to the USGS federal NHD**: All partners make approved updates directly to the USGS federal NHD using NHDGeoEdit tools and established processes (Option 2)*

   Reasons: For some time, major agency partners (i.e., MPCA, USGS) have expressed interest in editing directly to the USGS federal NHD dataset and key staff have taken the necessary training to become authorized NHD editors. They would need to take additional steps to become official state "sub-Stewards". Direct editing by multiple stewards would remove the potential "bottleneck" of waiting for a single State NHD Administrative Steward to process edits. It also allows partners to have more control over specific features for their business needs. A collaborative interagency review process fosters "good will" towards the common goal of providing a single authoritative spatial hydrography dataset for Minnesota.

6. ***Updates to the MN state NHD**: The State Administrative NHD Steward replaces the state NHD on the GDRS with a copy of the updated federal NHD (Option 2)*

   Reasons: This is a simple operation that could potentially be automated. However, it *will* lead to an approximate 10-day lag between the dates that approved edits are uploaded to the USGS federal NHD and when they appear in the state NHD on the GDRS. (Working with USGS will hopefully reduce this time frame.) Partners will need to plan the migration of their event data around this schedule.

Watershed Data Maintenance

As updates are made to the DNR Catchments in the future, the two data collections need to remain synchronized. It must be noted that edits occasionally occur in the other direction, as when an effort to "harmonize" the watershed data across the US-Canada border resulted in some changes on the Minnesota side. The fact that there may be updates to the DNR Catchments dataset from WBD must be considered in the maintenance workflow.

USGS has created a stewardship process and a "WBDEdit" tool, similar to its NHD Update tool for hydrography, to enable stewards to update watershed features as the need for individual corrections is identified. This particular tool and model does not fit well with current DNR plans for future updating of the Catchments data. DNR has essentially "frozen" the Catchments data until it can research and define a process which uses LiDAR data to do a complete update, and find the resources to accomplish this. This blanket replacement of WBD data based on revised Catchments is not trivial, but the process to do so was confirmed in the 2010-2011Catchments-to-WBD Synchronization, and USGS has indicated that they would work with the state to get the updates incorporated when the data became available. In order for this to work, DNR would need to continue to incorporate HUC-attributes into their Catchments dataset as it is revised.

Discussion

Unfortunately, no option (including the recommended option) is currently able to accommodate all of the hydrography features necessary to fully meet partner business needs. Within DNR, the feature classes for Public Waters basins, NWI features and DNR Catchments will still need to be maintained separately within the DNR Hydrography dataset (i.e., outside of NHD). NHD either lacks the necessary structures to store these features (i.e., Public Water regulatory basins; DNR Catchments) or the feasibility of adding these features to NHD has not been fully researched (i.e., NWI wetland polygons). There are probably additional feature datasets within other agencies for which this is also true.

In addition, NHD has no counterpart feature type to store "islands", which are prominent features in the DNR Hydrography Open Water layer. Adding a new feature type to NHD is not a simple process in general, and USGS has rejected the notion of adding island feature types into NHD because they are not true "water" features. Thus, DNR would need to maintain island features as a separate feature class outside of NHD. There are additional unresolved issues involving stream centerlines along state borders and the need to extend stream flowlines into lake polygons to allow for network path tracing in NHD. In general, these limitations have work-around solutions but they are not without additional inconvenience, inefficiencies, and/or impracticalities for agency data managers.

A further concern is that agencies often maintain highly sensitive data to meet statutory or business obligations. A good example is the Public Waters basin and watercourse delineations maintained by DNR for the purposes of regulatory mapping and permitting. Since these features have important legal implications, any attempts to reference them to a shared dataset such as NHD will require strict editing rules and quality control measures to ensure their accuracy. DNR is hesitant to expose this dataset to others within a shared environment. For now, at least, the DNR's Public Waters data will be maintained outside of NHD but managed for topological consistency with NHD.

Thus, the goal of having a truly *single, authoritative spatial hydrography dataset for all of MN features* is not fully achievable at this time. However, streams and open water features, which make up a good percentage of the features needed by most users, *could* be shared within a single state NHD dataset. Achieving this step would provide a good start towards the common goal.

Conclusion

The objective of this NEIEN grant project was to explore, review and test the feasibility of integrating the DNR and NHD into a single synchronized dataset for long-term maintenance of geospatial hydrography data. It has been proven that there are feasible technical solutions and the technical, management and strategic considerations for various options have been described in detail in this document. A workable solution has been recommended to meet at least some of the objectives. This solution, while not ideal, provides a "road map" towards geospatial hydrography data integration at the statewide level.

The next step will be for agency-level managers to initiate discussions regarding if, when and how to move this recommendation (or another solution) forward. This will involve a consideration of the costs, benefits and long-range plans of the partner agencies. It is our hope that this document will aid managers in the interagency collaboration towards a common goal for Minnesota.

Chapter 1a: Origins of the National Hydrography Dataset in MN and the DNR Hydrography Dataset

Origins

In 2002, as a high-resolution (1:24,000 or 24K) version of the **National Hydrography Dataset** started into production in other parts of the U.S., state and federal partners in Minnesota came together to discuss how best to develop a high-resolution NHD for Minnesota. The plan was to use core geospatial hydrography datasets maintained by DNR as the base features for NHD so that the datasets could start out synchronized and be easily updated.

DNR Source Data

The original DNR 24K Streams and 24K Lakes datasets (now considered legacy datasets) were developed over the period 1998-2003 according to the following lineages:

- **DNR 24K Streams:** DNR obtained *MnDOT Basemap* stream traces that had been digitized from USGS 1:24,000 topo maps.[i] A number of additions and improvements were made including spatially moving inflows and outflows to match NWI lake polygons, adding connectivity through lakes, wetlands, and 2-d river features, and correcting flow direction.

- **DNR 24K Lakes:** The DNR 1:24,000 Lakes were derived from a combination of *MnDOT Basemap* delineations and the original **National Wetlands Inventory** (i.e., NWI, circa 1990 based on 1980's vintage aerial photography). Lake open water and fringe wetland polygons were extracted from NWI to form the lake features.[ii,iii]

    - **DNR 24K Rivers** (i.e., riverine polygons also derived from NWI) were included within the DNR 24K Lakes dataset. The locations of stream inflows and outflows through NWI-derived lakes were moved from their original stream positions to corresponding points on the derived 24K lakes dataset because of better positional accuracy.

    - The new 24K lakes polygon dataset was intersected with the new 24K streams dataset to form spatially-integrated datasets with nodes at intersections. Data was tiled and distributed by major watershed.

Construction of High-Resolution NHD from DNR 24K Source Data

In March of 2002, USGS and EPA staff met with staff from MnGeo (then LMIC), MPCA and DNR to outline and confirm a set of decision steps for creating high-resolution (1:24,000-scale, 24K) NHD from base state DNR data. The idea was that, by using the DNR data as a base, it would be easier to keep the datasets synchronized and updated consistently. Major decision rules and steps were as follows:

- DNR 24K Streams (1-d features) were chosen as the basis for the NHDFlowlines.
- DNR 24K Lakes (2-d polygons) were chosen as the basis for the NHDWaterbody feature class (*Lake/Pond category*).
- The decision was made not to include wetlands (i.e., *Swamp/Marsh category*) in the NHDWaterbody feature class. The DNR 24K Lakes layer explicitly did not include most wetlands. There were some errors in the NWI wetlands that DNR did not want to see perpetuated in the NHD. (*Note:* DNR is working on an update to the NWI in 2014).
- DNR 24K Lakes (2-d riverine polygons extracted from NWI) were chosen as the basis for the NHDArea feature class (i.e., *River category)*
- The DNR 24K Lakes and DNR 24K Streams features were assigned USGS DLG feature codes (i.e., numeric codes representing stream and lake types).
- These datasets were used as the source input datasets for creation of the 24K NHD. Attributes from the existing 100K NHD were conflated onto the DNR input features. Additions and corrections were made as necessary through the "NHDCreate" tool QC steps. ("NHDCreate" was the predecessor to the current NHD Conflation toolset.)
- For HUC-8's extending into Wisconsin, Wisconsin DNR 24K hydrography linework was used as input and a similar feature type conversion was made to create the input data.

This methodology was used for producing NHD in most of Minnesota's HUC-8's where Minnesota agencies or USGS did the actual high-resolution NHD production. However, there were some exceptions:

- Where USGS contractors did the production work they did not necessarily use the above methodology, especially along the southern and western borders of the state, primarily where full HUC-8's contained portions of Iowa or the Dakotas. In these areas, the contractors used the more standard NHD Production approach: 1) they used the blue lines, either digitized or scanned, from the 24K topo maps (i.e., lakes, wetlands and rivers), 2) they added USGS DLG feature type codes, and 3) they conflated these lines using the medium-resolution (100K) NHD to assign attributes.

- Where USGS originally piloted high-resolution NHD production work (i.e., along the "Lower Mississippi" (0704) HUCs in Minnesota, many of which also extended into Wisconsin), USGS tested several methodologies. These included straight digitizing of features, use of pilot 24K USGS DLG lines, use of Minnesota DNR and Wisconsin DNR 24K hydrography delineations, and other methods to create the input data sets for conflation.

Even where the use of the state-outlined process resulted in a high-resolution NHD that was largely consistent with DNR's hydrography data, there were some inconsistencies from the beginning, which increased in number as the data sets were edited over the following decade.

Editing History

During and following the construction of the 24K NHD from DNR source data (2002-2005), improvements continued to be made independently to each dataset to meet specific agency needs. A good process for keeping things synchronized was lacking, as funding and available staffing were intermittent.

DNR Edits

Improvements to legacy DNR 24K and 100K hydrography datasets included re-delineation of many stream features and the creation of two new basin layers (i.e., Open Water basins and Public Waters basins) to meet DNR business needs.

- *Further DNR 24K Streams development included:*
  - Re-digitization of Fisheries-managed stream features in SE and NE MN to match 1991-1992 ortho-imagery, (2001-2004, DNR Fisheries).
  - Addition of Minnesota's legally defined trout streams to the streams feature class (in response to 1994 legal action brought against DNR by Minnesota Trout Unlimited and other partners). These streams are often very small and were not always on the original 24K topo maps (2000-2003, DNR Fisheries).
  - Assignment of DNR Kittle Numbers (i.e., DNR's unique stream ID's) to linear features comprising complete watercourses (2001-2010, 2014, DNR Fisheries).
- *Further waterbody development included:*
  - Creation of a **Public Waters (PW) basins** feature class derived from a new extract of NWI (1996-97). Public Water basins are delineations defined to the Ordinary High Water Level (OHWL) by Minnesota Statute *(M.S. 103G.005)* for regulatory purposes (1997-2012, DNR Eco-Waters). (See *Chapter 1: DNR Hydrography Dataset – Overview* for more detail.)
  - Creation of an **Open Water (OW)** basins feature class from the **USGS DLG 100K Hydrography** data source which already had DNR Lake IDs (i.e., DOWLKNUM) assigned from an earlier effort. Improvements included updating delineations for approximately 4300 lakes managed by DNR Fisheries, based mostly on 2003-04 FSA imagery (2001-2008, DNR Fisheries).

The DNR Hydrography Dataset

In 2012, DNR merged its "best available" hydrography features to form the new enterprise **DNR Hydrography Dataset** which effectively replaced the legacy 24K Streams and 24K Lakes datasets. (See *Chapter 1* for a complete description of this dataset.)

- The following five core feature classes were combined within a Feature Dataset in SDE:
  - *Measured Stream Routes*
  - *Open Water (OW) polygons*
  - *Public Water (PW) Basin polygons*
  - *DNR Catchment polygons*
  - *Hydrologic Points of Interest (HPOI).*

  Also included in the SDE database (but not within the above Feature Dataset) is the new *National Wetlands Inventory* (NWI, in progress 2014).

- For the Stream Routes feature class, the best linear features from three separate efforts were incorporated in a new DNR Hydrography Streams layer:
  - The DNR 24K Streams layer which included features re-digitized based on ortho-imagery and trout streams added by DNR Fisheries
  - Streams and connector features (both real and "interpreted") as digitized by the DNR Watershed Mapping Project
  - Ditches within Wildlife Management Areas (WMA's) digitized by DNR Wildlife
    - DNR Stream IDs (i.e., Kittle Numbers) were assigned to all stream features and they were dissolved to form individual measured routes for each watercourse. Measures are in miles, extending from mile 0 at the watercourse mouth and increasing to its upstream end.
    - All other data (e.g., stream type, stream order, etc.) is now maintained in event tables as linear events upon the stream routes.

- The Public Waters basins and Open Water polygons were kept in separate feature classes but integrated according to topology rules so that Open Water polygons are coincident with, or nest within, Public Waters basins.
  - Stream features were intersected with the newly integrated lakes layer so that nodes appear at intersections (i.e., inflows to and outflows from lakes pass through nodes on the lake boundary).
  - Streams representing lake outflows were aligned with DNR watershed pour points derived from the DNR Level 08 Catchments feature class.

- Topology rules were set within the Feature Dataset to govern relationships between feature classes. (Note that features are still being edited to conform to topology rules and complete integration among feature classes has not yet been achieved.)

- **As of 2012, the original DNR 24K and DNR 100K Lakes and Streams datasets are still available but are considered "retired" and are no longer supported.**

NHD Edits

At the same time that DNR was restructuring its internal hydrography geospatial datasets, updates were also being made to the high-resolution NHD. Some updates to the NHD were made by Minnesota agencies (i.e., Metropolitan Council, USGS-WRD-MN, MnGeo), but more were made by the USGS NHD Team directly.

- Edits made by the USGS NHD Team included: NHD "Maintenance" cycles, e.g., global improvements to topology, etc.; image integration of larger features to 2008 air photos; adding names from Geographic Names Information System (GNIS); Network Improvement Project (2012-2013); "migrating" hydrography features into their correct HUC designation when WBD was incorporated into the NHD; "data harmonization" with Canada and completion of entire HUC-8's along the US-Canada border (i.e., HUC-8's 0902, 0903).

- Edits made by Minnesota organizations included: a pilot project to add verified storm water features in the Twin Cities Metropolitan Area (Metropolitan Council); general edits, updates and improvements to lake and stream delineations and names; additions and deletions of features; edits to improve network preparatory to creating high-resolution **NHDPlus**; conflation update tool testing using edited DNR trout stream data as input (MnGeo).

As a result of the independent edits made to the layers over time, and despite sporadic efforts to coordinate and track updates being made on one system or the other, the Minnesota NHD and DNR Hydrography datasets are now significantly out-of-sync. While we knew this anecdotally, we did not have a good idea on how extensive the differences were.

Chapter 3 describes the results of a systematic comparison of NHD and DNR hydrography features for selected areas of the state. Differences between the two datasets are quantified for four pilot areas. It is necessary to understand the differences between the datasets in order to chart a suitable course for statewide synchronization, which is the first step towards long-term integration.

References

Chapter 1b: NHD Hydrography Dataset Overview

Chapter 1c: DNR Hydrography Dataset Overview

Cowardin, Lewis M., Virginia Carter, Francis C. Golet, and Edward T. LaRoe. ***Classification of Wetlands and Deepwater Habitats of the United States,*** U.S. Fish and Wildlife Service, Washington, D.C., 1979, p. 5 http://www.fws.gov/wetlands/Documents/Classification-of-Wetlands-and-Deepwater-Habitats-of-the-United-States.pdf(17 MB)[iii]

Maeder, Susanne. ***Minnesota NHD Issues Meeting (March 20, 2002) - Meeting Notes and Resolution Summary***, Land Management Information Center, St. Paul, MN, July 21, 2002 (unpublished report).

Minnesota Statutes and Rules: https://www.revisor.mn.gov/pubs/ State of Minnesota, 2013.

Shaw, S.P. and C.G. Fredine. ***Wetlands of the United States***. U.S. Fish and Wildlife Service, Circular 39, 1956[ii]

Metadata:

DNR 24K Streams (legacy): http://deli.dnr.state.mn.us/metadata/strm_baseln3.html

DNR 24K Lakes (legacy): http://deli.dnr.state.mn.us/metadata/lake_openwpy3.html

Original National Wetlands Inventory: http://deli.dnr.state.mn.us/metadata/wetl_nwipy3.html

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[i] The *MnDOT Basemap* data was created in the 1990's and digitized from paper maps, not stable base separates as recommended for using the equipment and technology at that time. It should also be noted that the *MnDOT Basemap* effort was intended to support MnDOT's county highway map program and did not include all content contained on USGS published maps at the time because of scale requirements. Nonetheless, the *MnDOT Basemap* data was the "best available" statewide data at the time. (Personal communication, Ron Wencl, USGS).

[ii] Circular 39 Types 3, 4, 5 wetlands and [iii] Cowardin classification codes PUBF, PUBH, PUBG and L1 features.

Chapter 1b: National Hydrography Dataset (NHD) Overview

Objective

This provides an overview of the **National Hydrography Dataset** for comparison to the **DNR Hydrography Dataset**.

Summary

- The **National Hydrography Dataset (NHD)** is the national framework hydrography theme, and provides the surface water component of The National Map. The dataset is used for mapping, analysis, linear referencing (addressing) of hydrography-related data, and network tracing
- The **Hydrography** component of NHD represents the surface water of the U.S. using common features such as lakes, ponds, streams, ditches, stream gages, and dams
- Drainage areas are represented by the **Watershed Boundary Dataset (WBD)**, a hierarchy of nested drainage hydrologic units (HUCs)
- Data are seamed at national borders with Canadian and Mexican data to create full HUC-8 hydrologic units over border areas.
- An extensive set of topology rules underlies the data model; those rules are enforced by the NHD Editing and QC Tools
- There is a medium-resolution (1:100,000) and a high-resolution (1:24,000) version of the dataset. Minnesota users of the NHD use the high-resolution dataset almost exclusively
- While the high-resolution dataset started with a 1:24,000-scale base, the high-resolution dataset can be updated with better-than-24K delineations where available, in order to present the "best available" data in any area
- Updates to the NHD are carried out by USGS and by a network of state, federal, and local stewards through a controlled stewardship process
- Beyond the Stewardship process administered by USGS, NHD editors within a single state can design their own system for communication and coordination of editing.
- A community of users, through participation in the NHD Management Team, NHD Advisory Team, and other participatory processes sponsored by USGS, helps to guide the development of the database over time.
- USGS provides access to the national NHD Distribution database via web mapping services, a data extract and download capability, pre-staged subregions (by HUC-4) and state extracts. Data downloads for editing are controlled by the stewardship process.

Dataset Description

Overview

The **National Hydrography Dataset (NHD)** is the national framework hydrography theme, and provides the surface water component of The National Map. The NHD is a comprehensive set of digital spatial data that represents the surface water of the U.S. using common features such as lakes, ponds, streams, ditches, stream gages, and dams. The dataset is used nationally for mapping, analysis, and linear referencing. Linear stream features form a connected geometric network that supports upstream and downstream tracing. Stream/River reach addressing enables linear referencing of other data to the stream network. Drainage areas are represented by the **Watershed Boundary Dataset (WBD)**, a hierarchy of nested drainage hydrologic units (HUCs). (*NHD Fact Sheet*)

The National Hydrography Dataset is stored at the United States Geological Survey's National Geospatial Technology Operations Center (NGTOC). While the federal system includes both a medium-resolution (1:100,000) and a high-resolution (1:24,000) version, Minnesota organizations using the NYD rely on the high-resolution data for their business needs. While the high-resolution started with a 1:24,000-scale base, the high-resolution dataset can be updated with better-than-24K delineations where available, in order to present the "best available" data in any area. Updates to the NHD are carried out by USGS and by a network of state, federal, and local stewards through a controlled stewardship process (described in Appendix 7b). The data is seamed with hydrography data from Mexico and Canada to create full HUC-8 datasets at national borders.

Data Structure

The National Hydrography Dataset consists of two feature datasets (i.e., Hydrography and WBD) and a set of associated tables.

The **Hydrography** Feature Dataset includes the following feature classes:

- HYDRO_Net /HYDRO_NET_Junctions (lines and points making up the stream flowline geometric network)
- **NHDArea** (river polygons)
- **NHDFlowline** (measured stream routes)
- NHDLine (lines)
- NHDPoint (points)
- **NHDWaterbody** (polygons)
- NHDAreaEventFC (polygons)
- NHDLineEventFC (lines)
- NHDPointEventFC (points)

The **WBD** Feature Dataset includes the following feature classes:

- WBDHU2 (polygons) also referred to as HUC-2
- WBDHU4 (polygons) also referred to as HUC-4
- WBDHU6 (polygons) also referred to as HUC-6
- WBDHU8 (polygons) also referred to as HUC-8
- WBDHU10 (polygons) also referred to as HUC-10
- WBDHU12 (polygons) also referred to as HUC-12
- WBDLine (lines)

Main NHD tables support feature-level metadata tracking, extracted version tracking, reach numbering history, value-added attributes, and flow tracking.

The critical features which we are interested in integrating at the state level are:

- For Hydrography
  - NHDFlowline
  - NHDArea
  - NHDWaterbody
- For WBD
  - WBD HU8, 10, 12 (the larger drainage regions can all be derived)

DNR Hydrography Dataset streams (measured routes) and open water (polygon) features correspond to the NHD Hydrography feature classes of NHDFlowlines and NHDWaterbodies, respectively. The DNR Catchments feature class is used to derive the larger WBD drainage basin data sets. DNR Major Watersheds (i.e., DNR Level 4) are the same as WBD HUC-8 (i.e., USGS Level 4, 8-digit) drainages.

Feature Class Descriptions- NHD Hydrography Feature Dataset (NHD Feature Catalog)

HYDRO_NET /HYDRO_NET_Junctions: The feature classes called Hydro Net and Hydro Net Junction contain the geometric network for the Hydrography Dataset with assigned flow direction for flowline features. Hydro_Net is an ESRI utility network, and Hydro Net Junction contains points for all flowline start and end nodes. These are produced when the NHD is extracted from the National Database and the network is given the name Hydro_Net.

NHDArea (polygons): These are area-defined hydrographic landmark features, such as 2-dimensional rivers, bays, areas of complex channels, inundation areas, and rapids.

NHDFlowline (measured routes): NHDFlowlines consist of (1-dimensional) routes that make up a linear surface water drainage network. Flowlines have a reach code and a measure, allowing for the establishment of upstream/downstream relationships. They can be further coded as stream/rivers, canal/ditches, artificial paths through 2-d rivers or lakes, pipelines, coastlines, underground conduits, or connectors.

NHDLine (lines): NHDLines represent linear NHD hydrographic landmark features used for cartographic representation. They can be dams, rapids, bridges, levees, waterfalls, or other linear features that do not participate in the drainage network. ***Minnesota had intended NOT to update these features in the NHD because there was no comprehensive local source for this data. However, USGS has advised that if NHD Area features are updated, then the NHDLine features could become out-of-sync.***

NHDPoint (points): NHDPoints contain points representing NHD hydrographic landmark features. Some points may have reach codes. Points may be dams, wells, gaging stations, rocks, sinks/rises, springs/seeps, lock chambers, water intakes or outflows. In this feature class, points are not referenced as events on NHD. If they are referenced as events, they are captured in the NHDPointEventFC feature class. ***Minnesota is choosing NOT to update these features in the NHD.***

NHDWaterbody (polygons): NHDWaterbodies contain regions representing area-defined NHD hydrographic waterbody features. Waterbody feature types of interest in Minnesota are LakePond, Reservoir, and SwampMarsh. LakePond and Reservoir features must have a reachcode, while reachcodes for SwampMarsh are optional.

NHDAreaEventFC (polygons): This is a placeholder for Area Events maintained by USGS. At the state level, MPCA has created area events for water management and EPA reporting.

NHDLineEventFC (lines): This is a placeholder for Line Events maintained by USGS. At the state level, MPCA has created line events for water management and EPA reporting.

NHDPointEventFC (points): Point events maintained by USGS include NID dams, USGS Stream Gages, NWIS Water Quality Monitoring Stations, and Divergence Structures. At the state level, MPCA has created point events for water management and EPA reporting.

The event data structure can be used by MN organizations to house events of interest to the state. MPCA has created point, line, and area events which are stored in NHD event format. These “local events” are not posted back to USGS for the national NHD.

Feature Class Descriptions- WBD Feature Dataset (NHD Feature Catalog)

Hydrologic Units represent a set of nested drainage areas, with the largest being Level 1, 2-digit (i.e., WBD HUC-2). For example, the HUC-2 code for the Missouri River Basin is "10", for the Souris-Red-Rainy Basin is "09", for the Upper Mississippi Basin is "07", and for the Great Lakes Basin is "04". The smallest hydrologic unit currently populated for Minnesota is WBD HUC-12 (i.e., Level 6, 12-digit).

WBDHU2 (polygons): Hydrologic Unit Level 2 – can be derived from WBDHU8

WBDHU4 (polygons): Hydrologic Unit Level 4 – can be derived from WBDHU8

WBDHU6 (polygons): Hydrologic Unit Level 6 – can be derived from WBDHU8

WBDHU8 (polygons): Hydrologic Unit Level 8

WBDHU10 (polygons): Hydrologic Unit Level 10

WBDHU12 (polygons): Hydrologic Unit Level 12

WBDLine (lines): Line representing WBDHU12 (or smallest available) boundary, some extensions into surrounding HUCs.

Several WBD feature classes are currently unpopulated:

- ***WBDHU14 (polygons):*** Hydrologic Unit Level 14
- ***WBDHU16 (polygons):*** Hydrologic Unit Level 16
- ***NonContributingDrainageArea (polygons):*** Drainage areas which are not hydrologically-connected to other drainage areas.
- ***NWISBoundary (lines):*** Boundary lines representing stream gages in the National Water Information System (*NWIS*).
- ***NWISDrainageArea (polygons):*** Polygons representing stream gages in the National Water Information System (*NWIS*).

Feature Class Rules (Topology Rules)

There is an extensive set of topology rules which are enforced by the NHD Editing and QC Tools. The most obvious to editors of NHD is that, where there is both a 1-dimensional and a 2-dimensional representation of a river feature (i.e., a 1-d "artificial path" NHDFlowline maintaining downstream connectivity through a 2-d NHDArea feature representing a wide river), the 1-d feature must be inside the 2-d feature.

NHD Data Maintenance

The United States Geological Survey (USGS) manages the National framework hydrography data layer, the NHD. USGS maintains the national version of the database, and the USGS-sponsored NHD Stewardship process manages updates to the data that can come from a large number of federal, state, and local partners that are registered as NHD data stewards.

Multiple data stewards (NHD editors) can be recognized within a state, with one designated as the Principal or State Administrative Steward, the primary point of contact between the USGS NHD Team and the state. Stewards are registered with NHD and can check out NHD data to edit through a process administered via the NHD stewardship website (http://usgs-mrs.cr.usgs.gov/stewweb/). Editing is generally done on a HUC-8 basis. If a HUC crosses a state or national boundary, stewards make edits only within their state's boundary. A reconciliation and posting process at the national level resolves editing conflicts. Appendix 7b describes the NHD Stewardship Process in detail.

Beyond the Stewardship process administered by USGS, NHD editors within a single state can design their own system for communication and coordination of editing.

Access to Data

USGS provides access to the national NHD Distribution database via web mapping services, a data extract and download capability (i.e., to extract one or more HUC-8's for desktop use), pre-staged subregions (by HUC-4) and pre-staged state extracts (including all full HUC-8's that cross state boundaries), and the controlled data checkout-check-in (replicate checkout) capability for NHD editing through the stewardship process.

At the state level, MnGeo posts the state extracts to the MN Geospatial Data Resource Site (GDRS). MnGeo and MPCA also currently keep the data in SDE.

Future Data Updates

MPCA and USFS have recently (*2014)* registered as NHD editors through the USGS stewardship process and would like to directly edit the NHD. In addition, much of the hydrography data updating in Minnesota is being done by DNR to the DNR Hydrography Dataset. This project grant was obtained to explore the methodology necessary to keep the NHD Dataset maintained with edits from multiple partners while continuing to meet the business needs of all users.

References

Appendix 7b: NHD Stewardship Process

- describes the NHD Stewardship Process as outlined by USGS

NHD web: Policy, tools, database definitions, and edit processes and procedures are defined by USGS on their NHD web page - http://nhd.usgs.gov. (NHD Home)

NHD Web: Data checkout and check-in for purposes of updating is tracked by USGS through the NHD Stewardship web page - http://usgs-mrs.cr.usgs.gov/stewweb/. (NHD Stewardship)

U.S. Geological Survey, National Geospatial Program Office, ***The National Map – Hydrography (Fact Sheet 2009-3054)***, Revised March, 2010. Available for download from http://pubs.usgs.gov/fs/2009/3054/pdf/FS2009-3054.pdf (*NHD Fact Sheet*)

USGS, National Geospatial Program Office, ***NHD Feature Catalog***, This Document explains the features, tables, and relationship classes that make up the NHD and the WBD. This catalog is now online. http://nhd.usgs.gov/userguide.html?url=NHD_User_Guide/Feature_Catalog/NHD_Feature_Catalog.htm (NHD Feature Catalog)

Chapter 1c : DNR Hydrography Dataset Overview

Objective

This provides an overview of the current **DNR Hydrography Dataset** for comparison to the **National Hydrography Dataset (NHD).**

Summary

- The DNR Hydrography Dataset is a single, authoritative statewide dataset of geospatial hydrography data layers built to meet the business needs of DNR and the wider GIS community.
- The core feature classes represent surficial hydrography features including streams, open water basins, public water basins, wetlands, watersheds and hydrologic points of interest.
- The DNR Hydrography Dataset is governed by topology and business rules that enforce geospatial relationships among features and ensure attribute consistency.
- Maintenance of the DNR Hydrography Dataset geospatial layers is performed by the **DNR Water Resources Team (WRT)** via a defined workflow.
- Numerous GIS layers are derived from the core feature classes of the DNR Hydrography Dataset and are distributed statewide via **the DNR Geospatial Data Resource (GDRS)** site and the **Minnesota Geospatial Commons** web portal.
- The DNR Hydrography Dataset plays a central role in supporting DNR’s statutorily-defined responsibilities for identifying and protecting aquatic natural resources.

Dataset Description

Overview

The **DNR Hydrography Dataset** was defined and structured from 2012-2014 by **the DNR Water Resources Team (WRT)**. This interdisciplinary team has the responsibility of maintaining this foundational dataset to meet a myriad of DNR business needs (see *Chapter 2 – DNR Business Needs*).

The concept for the enterprise DNR Hydrography Dataset was to provide a single, authoritative statewide dataset of geospatial surface hydrography features to replace the multiple, mismatched hydrography layers previously maintained by DNR. These include such legacy datasets as USGS 1:100,000 (100K) DLG Hydrography; NWI-derived 1:24,000 (24K) DNR Lakes**; National Wetlands Inventory (NWI)** circa 1990; MNDOT Basemap 1:24,000 (24K) Streams, etc. The collaborative nature of DNR programs and business needs, as well as those of external data users, prompted the desire to integrate the “best available” surface hydrography features into a single centralized dataset.

The following narrative describes the general structure and properties of the DNR Hydrography Dataset model. Note that (as of June 2014) the model has been documented but not yet fully implemented. (Refer also to *Chapter 1: Data Origins and Background* for a history of these data layers.)

- The DNR Hydrography Dataset is an ArcSDE Geodatabase whose feature classes are housed within a Feature Dataset. The core feature classes are (*Figure 1.1*):
    - Open water basins (polygons)
    - Public water basins (polygons)
    - Stream centerlines (measured routes)
    - DNR Level 08 catchments (polygons)
    - Hydrologic Points of Interest - HPOI (points)

    - National Wetlands Inventory – NWI (polygons)
      Note: this incomplete data layer is included in the SDE database but not within the above Feature Dataset

Feature class descriptions

Open Water (OW) Basins (polygons): Waterbody delineations based upon the visible and/or interpreted exposed water component of the basin as identified on aerial photography. These delineations are subject to frequent change based upon fluctuating water levels in any given season. Under ordinary conditions, open water delineations nest completely within and/or share common boundaries with Public Waters (PW) basin delineations. This feature class is originally based on USGS 100K DLG hydrography with extensive re-digitizing of important managed water features. Basins are attributed with unique DNR Lake Number IDs and official names as recorded in the **DNR Fisheries Lake Survey Database** (which matches DNR Lakes DB for Public Water Basins**;** see *Key Related Databases*, below).

Public Waters (PW) basins (polygons): Waterbody or wetland delineations delimited by the **Ordinary High Water Level (OHWL),** which is defined in Minnesota Statute *(M.S. 103G.005)* for regulatory purposes. These delineations represent the landscape "containers" for water on the landscape and are less subject to annual fluctuations in water levels than Open Water delineations. This feature class is originally based on 1990 24K NWI hydrography (obtained in 1996-97) with extensive re-digitizing of Public Water features. Basins are attributed with unique PW Basin IDS (i.e., DNR Lake Number IDs) and official PW names as recorded in **DNR Lakes DB** (see *Key Related Databases*, below).

Stream Centerlines (measured routes): Linear features representing stream and river centerlines, including ditches and artificial (interpreted) flow connectors. Routes are digitized in the direction of water flow. Routes have mile measures extending from mile 0 at the mouth and increasing to the upstream end (in the opposite direction of water flow). This feature class is originally based on MNDOT 24K Basemap data with extensive re-digitizing of linear stream features. Routes are attributed with unique watercourse IDS (i.e., DNR Kittle Number IDs) and Fisheries-assigned DNR Kittle names.

DNR Level 08 Catchments (polygons): Polygons representing the direct contributing land area that drains to a pour point, most often associated with a Public Waters basin of 100 acres in size or greater. Catchments are "chained" through their upstream attributes to define the entire upstream contributing area (watershed) for individual pour points. DNR Catchment polygons are dissolved to create different levels of nested watersheds for the DNR Watershed Suite and the USGS Watershed Boundary Dataset (WBD). This feature class was originally created through the *DNR Lake Watershed Mapping Project* which began in 1998[ii].

Hydrologic Points of Interest - HPOI (points): These are point features including water control structures, dams, catchment pour points, etc. They are aligned with (snapped to) linear features and may play a role in hydrologic modeling and DEM conditioning. This feature class is not currently populated; features will come from a variety of existing (mostly internal) data sources.

National Wetlands Inventory (NWI): An updated version of the federal wetland inventory for Minnesota (in progress, 2014) representing all wetlands and deep water habitats as identified through current remote sensing efforts. Polygons are classified by wetland type at a finer sub-division than Open Water features and include many more types of waterbodies. NWI features may become a source of new features for the Open Water feature class in the near future.

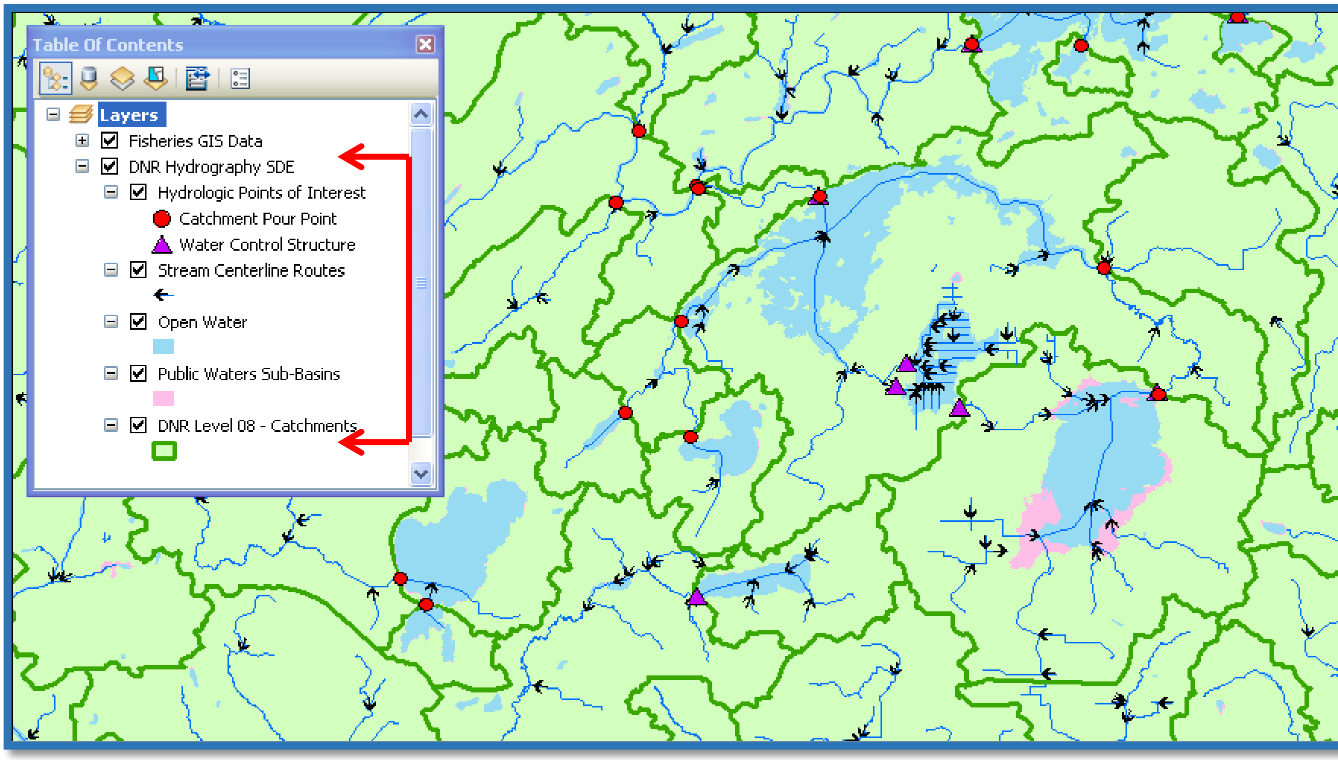

Figure 1-1. *Core feature classes within the DNR Hydrography Dataset (NWI not pictured)*

Feature class rules

The core feature classes are related within the feature dataset by the following topological rules:

- Open Water polygons are covered by (nest within) Public Water polygons
- Public Water polygons are covered by (nest within) DNR Catchment polygons
- HPOI points align with (snap to) linear stream features

The core feature classes are related within the feature dataset by the following business rules:

- *Stream linear route features:*
  - Have a unique Stream ID (Kittle Number) and name (Kittle Name) assigned by DNR Fisheries staff
  - Are continuous linear features having a digitized directionality representing flow
  - Have mile measures starting at the mouth (0) and increasing in an upstream direction

- *Open Water basins:*
  - Inherit Lake ID identifiers from the Public Waters basins they nest within
  - Inherit waterbody names from the Public Waters basins they nest within
  - If no Public Waters basin exists, Lake ID and waterbody name come from DNR Lakes DB

- *Public Waters basins:*
  - Are assigned unique identifiers (i.e., DNR Lake ID = DOWLKNUM) as per DNR Lakes DB
  - Are assigned official waterbody names as per DNR Lakes DB

- *DNR Level 08 Catchments:*
  - Have a unique Catchment ID
  - Are assigned the Lake ID of the lake for which they represent the local drainage area
  - Are associated with a pour point (HPOI)
  - Are hydrologically-chained via their attributes to represent the total upstream drainage area corresponding to the pour point of the waterbody they contain

- *Hydrologic Points of Interest*
  - Have a unique HPOI_ID
  - Are point events referenced to linear stream features
  - Are aligned with (snapped to) linear stream features

- All core and derived feature classes are maintained and distributed in the DNR standard coordinate system projection: UTM NAD83 Zone 15

- All core and derived feature classes have detailed metadata that defines data lineage, attributes, domains and appropriate uses

Key Related Databases

DNR Lakes DB is DNR's authoritative (PostgreSQL) database regarding Minnesota's Public Water basins and wetlands. It includes the official DNR Lake IDs (i.e., DOWLKNUMs) and official Public Water basin names, both of which are assigned by DNR's Ecological and Water Resources Division (EWR). Public Water basins and wetlands obtain their IDs and names from this database. Official names are submitted by DNR to the U.S. Board on Geographic Names for approval and subsequent addition to the federal USGS **Geographic Names Information System (GNIS)** database (which provides names for NHD). Additional attributes in Lakes DB include Circular 39 (*Shaw and Fredine, 1956*) wetland types, PW classifications and current and historic water levels. (Note that official watercourse names are also managed by DNR EWR but are not loaded into the stream routes feature class.)

Fisheries Lake Survey Database is DNR's authoritative (Oracle) database regarding Minnesota lakes that have been surveyed at least once by DNR Fisheries. Attributes include DNR Lake IDs (i.e., DOWLKNUMs) and official lake names which are obtained from DNR Lakes DB. Additional attributes include county, acreage, watershed, fisheries management office and Schupp Lake Class [iii]; these attributes are added to the Open Water basins feature class via routine processes. All of the current and historic fish survey information associated with each lake is also stored within this database.

DNR Hydrography Dataset Maintenance

- Feature classes are edited and maintained by appointed members of the WRT team who are responsible for particular feature classes
    - Note that as of 2014, the WRT is developing formal **Data Governance** [i] guidelines for management of this enterprise dataset
- Edits made to a feature class are dated and signed as completed by the editor
- Triggers (currently email) notify other editors that a change has been made to features
    - *Note:* ArcGIS Workflow Manager is currently being investigated as a strategy to implement workflow and automate triggers (*Appendix 6b*)
- Events are updated by the editor at the same time that the feature is edited (if needed to update a derived product); alternatively, event changes may be "saved up" to perform at regular intervals
- When features or events have changed, derived products are updated by automated product drivers

DNR Derived Product Generation

The DNR Hydrography Dataset is the source for the majority of DNR's hydrography-related GIS layers. These are generally referred to as "derived products", as they are derived from the DNR Hydrography Dataset and distributed via the GDRS and Minnesota Geospatial Commons. Examples include: Designated Trout Streams, DNR Lakes and Open Water, DNR Shallow Lakes and the DNR Watershed Suite. (See *Appendix 1* for a full listing of DNR Hydrography-derived products).

Derived layer attributes are maintained in stand-alone tables (for polygons) and event tables (for linear features) which are linearly-referenced to core feature classes via common identifiers. All derived GIS layers are generated via automated scripts (i.e., drivers) either on a regular schedule or triggered by a modification date. All derived products (except for non-public layers) are exported to the GDRS and Minnesota Geospatial Commons web portal for statewide data distribution.

Specific maintenance procedures for each core feature class are summarized here:

- *Streams*
    - Stream Route feature IDs and attributes are maintained within the core feature class table
    - Derived stream data is maintained in linear event tables by Kittle Number ID and river mile
    - Derived stream data is displayed upon measured stream routes by mile measure
    - Linear events are exported as derived feature classes to the GDRS and MN Geospatial Commons

- *Open Water*
    - Open Water feature IDs and attributes are maintained within the core feature class table
    - Derived Layer feature IDs and attributes are maintained in stand-alone attribute tables
    - Attribute tables are joined to the Open Water feature class by unique ID
    - Polygons are exported as derived feature classes to the GDRS and MN Geospatial Commons

- *Public Waters*
    - Public Waters feature IDs and attributes are maintained within the core feature class table
    - Polygons are exported as feature classes to the GDRS and MN Geospatial Commons

- *DNR Level 08 Catchments*
    - DNR Catchment feature IDs and attributes are maintained within the core feature class table
    - Polygons are iteratively dissolved to produce Level 01 (HUC2), Level 02 (HUC4), Level 04 (HUC 8, DNR Majors), Level 07 (DNR Minors) and Level 08 (DNR Catchments) watersheds
    - Watershed polygons are exported as feature classes to the GDRS and MN Geospatial Commons

- *HPOI*
    - HPOI features are (will be) maintained in point event tables by Kittle Number ID and river mile
    - Point data is (will be) referenced to measured stream routes by mile measures
    - HPOI events are (will be) exported as various feature classes to the GDRS and MN Geospatial Commons

- NWI
    - Polygons are exported directly as feature classes to the GDRS and MN Geospatial Commons

Key Derived Layers

DNR generates more than 60 derived product layers from the DNR Hydrography Dataset. A few key derived products and their significance to the NHD-DNR integration effort are listed below:

Derived Stream Routes layers

- maintained as linear events on the Stream Centerlines (measured routes) feature class:

- *Stream Types* – this layer has stream types comparable to NHD Flowline Ftypes (*Appendix 4*)

    - Stream types are managed in event tables as linear events upon stream routes
    - When exported as a linear feature class, they have nodes at feature confluences and where features change stream type
    - Where features extend into or through polygons, the stream type is "lake connector" or "wetland connector", comparable to the NHD Ftype "artificial path"
    - Stream segments carry the Kittle Number ID which can be aggregated or dissolved on to identify entire watercourses (comparable to the GNIS Stream ID in NHD)
    - This derived product will be used for the statewide synchronization with NHD flowlines

- *Designated Trout Streams* – this layer shows the state designated trout streams and tributaries as defined by MN Rules *(M.R. 6264.0050)*

    - Designated trout streams are managed in event tables as linear events upon stream routes
    - By statute, designated trout streams and their tributaries have special protection status in order to protect and foster the propagation of trout
    - Designation is listed by county and public land survey (PLS) description (i.e., township, range, section); all tributaries to designated trout streams are protected within the PLS section for which the main stream is listed

- *Public Waters Watercourses* – this layer shows state Public Waters watercourses as defined by Minnesota Statute *(M.S. 103G.005)*

    - Public Waters watercourses are managed in event tables as linear events upon stream routes
    - Features include natural and altered watercourses with a total drainage area greater than two square miles, and
    - Natural and altered watercourses designated by the commissioner as trout streams (above)
    - This layer is used in the preparation of Public Waters regulatory maps published by DNR and for issuing permits via **MNDNR's Permit and Reporting System (MPARS)** online web application

Derived Public Waters layers - extracted from the Public Waters feature class:

- *Public Waters Basins* – this layer shows state public waters basins as defined by *M.S. 103G.005*
    - Features include the DNR Lake ID (DOWLKNUM) which allows for joining and relating to numerous other datasets, including *DNR Lakes DB*
    - This layer is used in the preparation of Public Waters regulatory maps published by DNR and for issuing permits via *MNDNR's Permit and Reporting System (MPARS)* online web application
    - This layer will need to be maintained outside of NHD as there is currently no NHD feature class to represent the regulatory OHWL delineations

Derived Open Water layers - extracted from the Open Water feature class:

- *DNR Water Features* – this layer has waterbody types comparable to NHD waterbody Ftypes

    - Features include the DNR Lake ID (DOWLKNUM) which allows for joining and relating to numerous other datasets, including *DNR Fisheries Lake Survey Database*
    - This derived product (selected features only) will be used for synchronization with NHD waterbodies
    - This derived product (selected features only) will be used for synchronization with NHD 2-D river features

Derived DNR Catchment layers – extracted and built from the DNR Catchments feature class:

- *DNR Level08 Catchments* – these polygon features are iteratively aggregated to form DNR Level 01 – 04 watersheds, which are comparable to WBD HUC02 -HUC08 watersheds, within the DNR Watershed Suite
- This derived product is the current source for Minnesota WBD watersheds and will be used in future update efforts (see *Chapter 10*)

Future Data Updates

Although the DNR Hydrography Dataset (in concept) contains the best available DNR hydrography data, it is widely recognized that many features are out-of-date, incomplete and/or do not match current aerial photography. The DNR Water Resources Team is currently discussing data sources and strategies to update the dataset, including replacing features with ones produced by the new National Wetlands Inventory (in progress, 2014) and LiDAR-derived products.

[i]References

Appendix 1: DNR Hydrography-related Derived GIS Products
- a list of hydrography-related GIS layers derived from the enterprise DNR Hydrography Dataset

Appendix 4: DNR vs. NHD Water Feature Type Comparison
- a crosswalk table showing comparable DNR and NHD water feature types

Appendix 6b: ArcGIS Workflow Manager
- an overview of ArcGIS Workflow Manager for Maintenance Option #1

Chapter 1a: Data Origins and Background

Chapter 2a: DNR Business Needs

Chapter 10: Watershed Updates and Integration

Minnesota Statutes and Rules: https://www.revisor.mn.gov/pubs/ State of Minnesota, 2013.

Schupp, Dennis H. ***An Ecological Classification of Minnesota Lakes with Associated Fish Communities***. Minnesota Department of Natural Resources, Investigational Report #417, 1992.[iii]

Shaw, S.P. and C.G. Fredine. ***Wetlands of the United States***. U.S. Fish and Wildlife Service, Circular 39, 1956

Vaughn, Sean. ***DNR Watershed Delineation Project: History, Methodology Terminology & Data Attribution,*** MNiT Services @ MN Dept. of Natural Resources, 2014.[ii]

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[i] Data governance refers to developing and integrating the processes, policies, standards, organization, and technologies required to leverage data as an enterprise asset.(Data Governance Winter Conference, Fort Lauderdale, FL November 2013) http://www.debtechint.com/dgwinter2013/.

[ii] Development of the DNR Catchments dataset, as well as detailed definitions, are covered in the referenced document.

[iii] A lake classification system developed by MN DNR based on lake morphometry, water chemistry and fish communities (http://files.dnr.state.mn.us/publications/fisheries/investigational_reports/417.pdf)

Chapter 2a : MN Department of Natural Resources (DNR)

Objective

To summarize the business needs of DNR for a comprehensive statewide geospatial hydrography dataset.

Summary

- Overview
  - The DNR has numerous statutory and programmatic responsibilities for assessing and managing Minnesota's waters
  - The major business needs for a surficial hydrography geospatial dataset include:
    - To provide a base set of features on which to reference aquatic resource data
    - To calculate statistical summaries for quantifying Minnesota's water resources
    - To perform GIS analyses for hydrologic modeling
    - To support statutory responsibilities, regulatory programs and legislative initiatives
    - To support management of water resources for public recreation, fish and wildlife habitat, and sustainable water use
  - **The DNR Hydrography Dataset** is an integrated set of geospatial feature classes and attributes built to serve DNR's specialized business needs (*Chapter 1*)
    - This dataset is widely recognized as a foundational geospatial hydrography dataset and has a large and diverse user base across Minnesota
    - DNR is not reliant on NHD for federal reporting; NHD is currently insufficient to meet DNR's business needs
- General requirements for a geospatial hydrography dataset includes:
  - "Best available feature representation" accurately depicting surficial hydrology as indicated on current aerial photos or as interpreted for business needs
  - Geospatially-related and topologically-integrated feature classes
  - Accurate and consistent attributes
  - Minnesota State Standard projected coordinate system (i.e., *UTM NAD1983 Zone 15*)
  - Minnesota State Standard metadata documentation
- Business-specific requirements for a geospatial hydrography dataset includes:
  - Feature classes representing Open Water polygons, Public Water polygons, Streams with Kittle Numbers and Mile Measures, Watersheds, Hydrologic Points of Interest (HPOI), Wetlands
  - Specialized attributes to meet the business needs of multiple divisions within DNR

- The ability to derive and replicate current base hydrography and derived product layers using current or newly defined processes
- Easy accessibility by WRT staff to efficiently maintain and update base hydrography

Details

Hydrography-Related Business Needs of the MN DNR

The mission of the **Minnesota Department of Natural Resources (DNR)** is "*to work with citizens to conserve and manage the state's natural resources, to provide outdoor recreation opportunities, and to provide for commercial uses of natural resources in a way that creates a sustainable quality of life*".

The DNR protects the state's natural heritage by conserving the diversity of natural lands, waters, and fish and wildlife that provide the foundation for Minnesota's recreational and natural resource-based economy (*Minnesota Statutes 84, 97A*). These legal responsibilities are outlined in MN Statutes and MN Rules (see *Appendix 2a*).

DNR has a major (but not exclusive) responsibility for assessing and managing waters of the state in regards to conservation of water resources for Minnesota's diverse plants, fish , wildlife and human populations. The DNR has many areas of emphasis regarding water which can generally be lumped under the following categories:

- Survey, assessment and mapping of lakes, streams, groundwater, wetlands and watersheds
- Survey, management and mapping of biological populations (including plants, fish and wildlife)
- Acquisition and protection of aquatic communities, habitats and ecosystems
- Quantification and monitoring of water resources including water levels, use and availability
- Permitting of water appropriations, water-related work projects and shoreland activities
- Enforcement of laws and regulations regarding use of natural resources
- Management of dams and water control structures
- Hydrologic modeling of floodplains, floods, droughts, climate and watersheds
- Management of aquatic resources for recreational opportunities
- Education and research of aquatic ecosystems
- Long-term planning and management at the watershed scale

The DNR fulfills its statutory responsibilities through a variety of specialized programs (see *Appendix 2b*). To support these programs, DNR collects large amounts of data related to streams, lakes, wetlands, watersheds and biological populations. These data have a geographic component and must be referenced to geospatial data layers in order to map, analyze and report on Minnesota's aquatic resources. A separate Minnesota statute (*MN 103A.401*) outlines the DNR's responsibility to maintain a *statewide water information system*, of which geospatial hydrography data is a vital component.

> **MN Statute 103A.401: STATEWIDE WATER INFORMATION SYSTEM**
> The commissioner of natural resources, in cooperation with other state agencies, including the Minnesota Geologic Survey, shall establish and maintain a statewide water information system to gather, process, and distribute information on the availability, distribution, quality and use of waters of the state. Local, regional, and state governmental units and their

officers and employees shall cooperate with the commissioner to implement and maintain the statewide water information system.

Uses of DNR Geospatial Hydrography Data

For DNR, the major business uses of surficial hydrography geospatial data are:

- To provide a base set of features on which to reference diverse types of aquatic resource data. Once referenced to geospatial features, numerous derived product geospatial layers are generated for the DNR's **Geospatial Data Resource Site (GDRS)** and the **Minnesota Geospatial Commons** web portal. These layers are used to:
    - Create maps and reports
    - Provide data for DNR web-based applications
        - e.g., Recreation Compass, LakeFinder, Minnesota Permitting and Reporting System (MPARS), etc.
    - Support numerous natural resource initiatives, including Clean Water Legacy and LCCMR-funded projects
        - e.g., watershed-related planning and research, conservation targeting tools, sentinel lakes long-term monitoring effort, etc.

- To produce statistical summaries of geospatial attributes such as watershed area, stream sinuosity, lake volume and statewide counts of lakes and streams. These summaries help DNR to quantify, manage and conserve the diverse waters of Minnesota.

- To perform GIS analyses using geospatial operations which rely on specific dataset structures and attributes. Examples include DEM conditioning and hydrologic modeling using stream network connectivity, and watershed budget analysis using upstream catchment tracing.

- To support MN statutory obligations (e.g., Public Waters identification and mapping), MN Rules (e.g., transportation of water from infested waters), regulatory programs (e.g., water use appropriations) and legislative acts (e.g., Minnesota Wetland Conservation Act).
  See *Appendices (2a) MN Statutes and Rules, (2b) DNR Programs and (2c) Public Waters.*

- To manage and support water resources for public recreation, fish and wildlife habitat, and sustainable water use.

General Data Requirements

In general, DNR requires accurate delineations of surficial hydrographic features including lakes and open water, public waters, wetlands, streams, rivers, ditches, watersheds and hydrologic points of interest. Delineations should consist of "best available features", reflecting reasonably accurate representations of hydrography and landscape features as seen on (or interpreted from) current aerial photography. Features must be stored in distinct feature classes that are geospatially integrated with and topologically-related to each other in a comprehensive, statewide dataset. All feature classes must be projected in the Minnesota state standard projection (e.g., UTM NAD1983 Zone 15). In addition, features must have accurate and consistent characteristics as reflected via attributes (e.g., waterbody names, wetland types, stream types, etc.) All feature classes and derived layers must be fully documented via standard metadata.

Currently, the DNR Hydrography Dataset fulfills the above general requirements as well as the business-specific requirements listed below.

Business-Specific Data Requirements

In order to provide base features for its many tabular datasets and derived products, DNR requires the following feature classes, characteristics and attributes within a geospatial hydrographic dataset:

- **Open Water polygons**
  Features must represent: open water as seen on current aerial photography, including islands, wetlands, riverine features, artificial basins and intermittent hydrography features.

  Attributes must include: DOW Lake ID, Public Waters waterbody name, open water waterbody type, area (acres), perimeter (shoreline miles).

  Necessary for: derived open water layers; joining/relating to Fisheries Lake Survey tabular data.

- **Public Water polygons**
  Features must represent: the ordinary high water level (OHWL) as delineated by hydrologists using NWI base features and a variety of ancillary data (e.g., topographic contours, LiDAR, vegetation, soils, etc.)

  Attributes must include: DOW Lake ID, official Public Waters waterbody name, Public Waters class, wetland type, area (acres), perimeter (shoreline miles).

  Necessary for: Public Waters regulatory layers and maps; derived Public Water layers; joining/linking to Lakes DB tabular database.

- **Stream Route linear features**
  Features must represent: the centerlines of rivers, streams and ditches, including artificial connectors that run through waterbodies and connect landscape features. Features must have a digitized directionality to match the direction of water flow. Features must also have mile measures that begin at mile 0 at the feature mouth and increase with length to its end node (i.e., opposite direction of water flow).

  Attributes must include: DNR Kittle Number ID, stream name, stream type, length (miles).

  Necessary for: base reference layer for linear and point events; derived stream layers; mile measures for DNR Fisheries field activities (GPS navigation).

- **Catchment polygons**

  Features must represent: the smallest manually delineated drainage area that contains all land areas, as well as non-contributing inclusions and water features, upstream from the pour point (watershed outlet) of a waterbody (generally completed for lakes of 100+ acres only.)

  Attributes must include: CATCH_ID, DOWLKNUM (DNR Lake ID of associated lake), DOWN_CAT (downstream catchment), UPADJ_CAT (adjacent upstream catchments), HPOI_CLASS, HUC12_ID, Area (acres).

  Necessary for: base layer for all DNR-level watersheds (for DNR Watershed Suite) and HUC-level watersheds (for WBD); DNR Hydrography Toolbar tracing (upstream/downstream tool).

- **Hydrologic Points of Interest**

  Features must represent: dams, water control structures, gauges and other hydrologically-important features represented as points. Features must align with (be snapped to) other hydrologic polygon and linear features.

  Attributes must include: HPOI_ID, HPOI_CLASS, CATCH_ID.

  Necessary for: base layer for all HPOI derived layers; DEM conditioning; hydrologic modeling.

- **National Wetlands Inventory**

  Features must represent: All wetlands and deepwater features larger than 0.5 acres as defined by Cowardin et al. (1979).

  Attributes must include: ATTRIBUTE (wetland classification code), Wetland_Type (description) HGM_CODE (hydrogeomorphic classification code), Landscape (description), Landform (description), WaterFlow (description), HGM_Name, LL_CLASS (description), area (acres).

  Necessary for: depicting wetlands and deepwater features for wetland management, protection and restoration.

Reasons why DNR has not adopted NHD

Unlike MPCA and USFS, DNR does not have a regulatory or federally-mandated business need for NHD. Instead, DNR has for many years maintained its own set of hydrography layers which were derived from legacy data sources. Over time, these have evolved into a highly specialized set of geospatial features and attributes called the **DNR Hydrography Dataset** (*Chapter 1*) which serves DNR's diverse and specialized business needs.

NHD (in its current state) does not have sufficient features or attributes to meet these business needs. DNR uses unique agency IDs to identify geospatial hydrography features and reference them to tabular data; however, NHD doesn't carry these attributes. DNR stream route features are measured in river miles, which is inconsistent with the NHD flowline unit of measure. NHD has no current feature class in which to store islands or DNR Public Water basins, which represent regulatory delineations to the Ordinary High Water Level (OHWL). The **Watershed Boundary Dataset (WBD),** which stores the watershed component of NHD, is unable to store the DNR's high-resolution watersheds (i.e., DNR Level08 Catchments).

From a data management perspective, NHD is a complicated model that requires specialized training and USGS-created tools to maintain its data. Changes to the state NHD dataset need to be synchronized with the federal dataset, resulting in a time lag in waiting for submitted edits to appear in the updated MN version of NHD. There are several different agencies authorized to edit NHD. Conversely, DNR currently has exclusive control of its DNR Hydrography Dataset and can make changes for immediate addition to its derived products. Although it may be physically possible for DNR to reference its data as events to the NHD framework, the time and difficulty in doing so has (thus far) prevented DNR from adopting NHD as its base hydrography dataset.

Perhaps most importantly, DNR has very specific responsibilities and obligations defined by Minnesota Statute and much of the hydrography data has specifically evolved to meet these needs. It is imperative that the geospatial data remains readily available to DNR staff for responsive and accurate maintenance. These data layers have important legal implications (e.g., Public Waters basins, Designated Trout Streams); thus, DNR would be resistant to allowing external editors to modify the underlying features or to have this data housed outside of DNR. (See *Appendix 2c: Public Waters*.)

Integration Considerations

As stated above, the DNR Hydrography Dataset fulfills all of DNR's specific business needs. However, <u>if</u> the NHD dataset was synchronized with the DNR Hydrography Dataset and <u>also maintained with the necessary associated attributes</u>, the DNR *could* use NHD as its hydrographic base with at least some DNR derived layers (e.g., dams, designated trout streams, shallow lakes) referenced to NHD as point, line and polygon events. In order to fulfill DNR's data needs under this scenario, it would be necessary to demonstrate that DNR's current base data layers can be fully replicated from NHD. *Appendix 8* describes this process in detail.

References

Appendix 2a: 2013 MN Statutes & MN Rules
– lists MN Statutes and MN Rules for water-related topics only

Appendix 2b: DNR Programs and Functions
– lists DNR Programs and Functions for water-related topics only

Appendix 8: DNR Event-Referencing Strategies
– outlines DNR testing of referencing data to NHD as events and generating DNR derived products

Chapter 1a: Data Origins and Background

Chapter 1c: DNR Hydrography Dataset Overview

Cowardin, Lewis M. , Virginia Carter, Francis C. Golet, and Edward T. LaRoe, *Classification of Wetlands and Deepwater Habitats of the United States,* U.S. Fish and Wildlife Service, Washington, D.C., 1979, p. 5 http://www.fws.gov/wetlands/Documents/ Classification-of-Wetlands-and-Deepwater-Habitats-of-the-United-States.pdf (17 MB)

Minnesota Statutes and Rules: https://www.revisor.mn.gov/pubs/ State of Minnesota, 2013.

Chapter 2b: United States Geological Survey (USGS)

Objective

To summarize the business needs of USGS for a spatial hydrography dataset.

Summary

- Hydrography is a framework data theme for the USGS, supporting the USGS “Water” mission
- The Hydrography framework data theme includes both the National Hydrography Dataset (NHD) and the Watershed Boundary Dataset (WBD)
- NHD is used to portray surface water features on The National Map, and supports mapping by USGS as well as many other organizations
- NHD is used to support analysis, including network tracing and upstream/downstream relationships, by USGS and other organizations.
- The high-resolution NHD, originally based upon a 1:24,000-scale map delineation, can now be edited, with the input of local knowledge and new data sources, such as imagery and LiDAR, to provide a “best available” level of detail for hydrography
- The USGS NHD Stewardship Process is in place to enable the input of local knowledge within the guidance of a national framework.

Details

The United States Geological Survey (USGS) is a bureau within the U.S. Department of Interior. Information about the role of the “Water” mission within the USGS organization, and how the NHD supports that mission, is extracted from the USGS web pages.

“As the Nation's largest water, earth, and biological science and civilian mapping agency, the U.S. Geological Survey (USGS) collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems. “ (*About USGS*)

“Water is one of the six science mission areas of the U.S. Geological Survey (USGS). Water’s mission is to collect and disseminate reliable, impartial, and timely information that is needed to understand the Nation’s water resources.” (*Water Resources*) This information includes data about stream flow reporting, statistics, and estimates, flood mapping, flood and drought, watershed modeling, water quality, water use reporting, and ground water.

A related mission is “Core Science Systems” - “Data about Earth and its resources are only useful if available in a format that is understandable and accessible. The U.S. Geological Survey (USGS) provides the Nation with ready access to natural science information that supports smart decisions about how to respond to natural risks and manage natural resources.” (*Core Science*) One component of the “Core Science Systems” is the National Geospatial Program (NGP).

The National Geospatial Program includes The National Map and the National Spatial Data Infrastructure (NSDI) – which includes a set of Framework Mapping themes for the U.S., one of which is Hydrography. The Hydrography data theme now includes both the National Hydrography Dataset (NHD) and the Watershed Boundary Dataset (WBD).

One primary use of the NHD is to support mapping. “The National Hydrography Dataset (NHD) and Watershed Boundary Dataset (WBD) are used to portray surface water on The National Map. The NHD represents the drainage network with features such as rivers, streams, canals, lakes, ponds, coastline, dams, and stream gages. The WBD represents drainage basins as enclosed areas in eight different size categories. Both datasets represent the real world at a nominal scale of 1:24,000-scale, which means that one inch of The National Map data equals 2,000 feet on the ground. To maintain mapping clarity not all water features are represented and those that are use a moderate level of detail.” (*NHD Home*)

Another primary use of the NHD is for analysis to support water science. “The NHD and WBD are often used by scientists using GIS. GIS technologies take advantage of a rich set of attributes imbedded in the data to generate specialized information. These analyses are possible because the NHD contains a flow network that allows for tracing water downstream or upstream. The NHD and WBD use an addressing system based on reach codes and linear referencing to link specific information about the water such as water discharge rates, water quality, and fish population.” (*NHD Home*)

The dataset supports many types of analysis. For example: “The WBD exists in six levels of a nested hierarchy permitting the analysis to determine which drainage basin a particular location is enclosed in. This makes it possible to determine which rivers and lakes could be affected by an event such as a toxic spill. Using basic NHD features like flow network, linked information, and other characteristics, along with one of the six levels of WBD areas, it is possible to study cause and effect relationships, such as how a source of poor water quality upstream might affect a fish population downstream.” (*NHD Home*) Data are “harmonized” across the US-Canada and US-Mexico borders so that complete drainage areas can be studied.

While the original high-resolution NHD was captured largely from the USGS 1:24,000-scale topographic map series, the information can now be updated to include local knowledge, newer information from aerial imagery, and a higher density of drainage as extracted from LiDAR data. This higher level of detail can support improved science applications, while it can also be generalized to meet the needs of The National Map. Future versions of the topographic map series will be based on improved inputs of hydrography, transportation, elevation, etc., as input base layers.

The Stewardship process is a key component of the NHD. To update the data, USGS partners with federal, state, tribal, and local agencies in a stewardship model that enables the input of local knowledge within the guidance of a national framework, with USGS and federal partners providing data management, tools, and quality control.

In early 2014, the USGS initiated an NHD Stewardship Assessment to solicit information from each state to evaluate the status, direction and needs of NHD stewards. The data from the survey is currently undergoing review and results will be provided to respondents and the broader user community in the near future.

USGS has outlined its plans for future development of the NHD to meet user needs in a "Hydrography Vision Statement" for 2014-2016 (*Hydrography Vision*).

References

Web: ***About USGS***: http://www.usgs.gov/aboutusgs, USGS/DOI, 2014 (About USGS)

Web: ***Water Resources of the United States***: http://www.usgs.gov/water/, USGS/DOI, 2014 (Water Resources)

Web: ***Core Science Systems***: http://www.usgs.gov/core_science_systems/, USGS/DOI, 2014 (Core Science)

Web: ***Hydrography – National Hydrography Dataset/Watershed Boundary Dataset***: http://nhd.usgs.gov/index.html, USGS/DOI, 2014 (NHD Home)

U.S. Geological Survey, ***Hydrography Product Information Document – Hydrography Vision 2014-2016***, http://nhd.usgs.gov/documents/Hydrography_PID_092313.pdf, 2013 (Hydrography Vision)

Chapter 2c: MN Pollution Control Agency (MPCA)

Objective

To summarize the business needs of MPCA for a comprehensive statewide geospatial hydrography dataset.

Summary

- MPCA has delegated authority from EPA to carry out provisions of the Clean Water Act
- State water program responsibilities include statewide water assessments and watershed protection and restoration strategies, as well as permitting, compliance, and data management
- For federal Clean Water Act responsibilities, EPA requires that all reporting be tied to the NHD
- MPCA's water data collection reporting units are referenced to the NHD as "events"
- MPCA reports to EPA for the following water-related programs under the Clean Water Act: Clean Water Act 305(b) Assessed Waters, 303(d) Impaired Waters (IR); Ambient Water Quality Monitoring Results (WQX); and Beach Environmental Assessment and Coastal Health (BEACH).
- MPCA's activities representing their highest needs for the NHD include surface water quality monitoring and assessment, modeling, and permitting.
- A strong state NHD stewardship effort is required to enable local updates of the data to meet the aforementioned business needs

Details

As outlined in its FY 2014-2015 state legislative overview, the MPCA's mission is "to protect and improve the environment and enhance human health." In support of that mission, the agency's work is structured to fulfill a number of strategic vision statements. Its vision as it applies to the state's water resources is: "Minnesota's clean water supports aquatic ecosystems, healthy communities and a strong economy" (Budget Overview).

MPCA has the major (but not exclusive) responsibility for assessing, maintaining and improving water quality in the state. MPCA has delegated authority from the U. S. Environmental Protection Agency (EPA) to carry out provisions of the federal Clean Water Act with its own monitoring, assistance and enforcement programs. For the Clean Water Act, EPA establishes guidelines, objectives and limits, and provides technical and financial to states to help in enforcing the Act (*MPCA Web*).

In addition, MPCA carries out many state-initiated water quality programs. These include:

- Completion of statewide water assessments and watershed restoration and protection strategies (WRAPS) (supported by the Clean Water Fund), and
- Permitting, compliance and data management supported by state General Fund appropriations (*Budget Overview*).

To support these programs MPCA collects data related to streams, lakes and watersheds. These data have a geographic component and need to be referenced to a GIS base.

For federal Clean Water Act responsibilities, EPA requires that all reporting is tied to the National Hydrography Dataset. Reporting of business data is usually described by watershed and any reported data associated with lakes or rivers must be referenced to the NHD. Reporting units must be tied to the NHD, via linear referencing, as "events". "Events" are any characteristic or quality or activity that can be referenced to a river or lake "address". Events provide a means for referencing tabular data collected by MPCA to the geography of the state's hydrography network. MPCA creates events on the NHD to support both EPA-required and local programs.

MPCA reports to EPA for the following water-related programs: Water Quality Integrated Reporting under the Clean Water Act: 305(b) Assessed Waters, 303(d) Impaired Waters (IR); Ambient Water Quality Monitoring Results (WQX); and Beach Environmental Assessment and Coastal Health (BEACH).

These require the reporting of both tabular data and information pertaining to geography: for example, for 2014 Integrated Reporting of Assessed Waters 305(b) and Impaired Waters 303(d), MPCA reports data and GIS files representing the areas assessed.

For MPCA, major business needs for their hydrography layers are:

- to accommodate all MPCA events
- to fulfill all of MPCA's reporting requirements to EPA

In view of the significant federal reporting requirement that requires the use of the National Hydrography Dataset, MPCA has adopted this database as the base to support its water resources mission.

The NHD is the foundation upon which MPCA's surface water monitoring, assessment and reporting activities are based. As a result, the MPCA staff needs the NHD to accurately depict the network of surface water features as they exist on the ground on an ongoing basis. This requires that they be able to add features of interest that are not currently represented in the NHD, correct errors they find in the existing NHD, or update features that have substantially changed in some way (e.g., course, extent, connectivity, or type). The only reasonable way to accomplish this is by supporting a robust stewardship process that enables local users to make these changes (*NHD Stewardship Survey*).

For MPCA use of the NHD, the three highest needs are for:

- **Surface Water Quality Monitoring and Assessment**
  NHD meets needs for Positional Accuracy, Currency, Topology, Scale and Feature Content (with the caveat that MPCA occasionally needs to add features – for instance, to add missing lakes or stream segments that are being assessed or monitored.
- **Modeling**
  NHD meets needs for Positional Accuracy, Currency, Topology, Scale and Feature Content – could additionally use flow data, for instance, as in NHDPlus (mean annual/mean monthly flow).

- **MPCA Permitting**
  NHD meets needs for Positional Accuracy, Currency, Topology, Scale and Feature Content. In general, positional accuracy is adequate.

References

MPCA FY 2014-2015 State Legislative Budget Overview. (Budget Overview)
http://www.pca.state.mn.us/index.php/view-document.html?gid=19143

MPCA Web Page: "Clean Water Act 40 Years Later" (MPCA Web)
http://www.pca.state.mn.us/index.php/about-mpca/mpca-news/news-releases-2012/hows-the-water-much-better-after-40-years-of-the-clean-water-act.html

USGS NHD Stewardship Survey 2014, MPCA response by Mark Olsen 3/17/2014 (NHD Stewardship Survey)

Chapter 2d: United States Forest Service (USFS)

Objective

To summarize the business needs of USFS for a spatial hydrography dataset.

Summary

- It is the established USFS Region 9 policy that NHD is the authoritative hydrography layer and WBD the authoritative watersheds layer of the Forest Service. Minnesota is in Region 9.
- USFS is moving towards accessing a central database version of NHD/WBD, periodically replicated from USGS.
- USFS is interested in stewardship and local editing of the NHD; Region 9 staff have received NHD Editor training.
- NHD is used in conjunction with national applications for watershed improvements and aquatic resources databases.
- Critical mapping applications using NHD include supporting FSTopo Mapping and Interactive Visitor Mapping. These applications represent near-term needs for having improved NHD data over national forest areas.
- Forest Plan Revision also requires reference to the hydrography data.

Details

USGS Input

National USGS Staff – Eastern Region 9

USFS staff representing the Eastern Region (Region 9, which includes Minnesota) provided the following information on regional use of the NHD and planned stewardship activity.

- It is the established Region 9 policy that NHD is the authoritative hydrography layer and WBD the authoritative watersheds layer of the Forest Service. Other USFS regions have adopted NHD and WBD, but there is no clear national policy. |

- National reporting requirements on Watershed activities and projects, however, do assume the use of WBD for identification and area purposes.

  - There are currently no national reporting requirements or performance measures that address NHD.

    - NHD and WBD are essential and assumed used for official national (published) mapping activities.

- USFS is working with individual forests to move away from having individual, local databases, to all accessing a version of the NHD. Forest Service enterprise databases are becoming the database of record for national reporting, and NHD is an important base dataset for this effort.

- **Access to NHD:**
    - USFS has a Read-Only copy of the NHD for the entire system.
        - NHD is replicated from USGS approximately quarterly, or upon request.
        - Region (9) requests a new extract periodically. This is done for the entire Region, but only for subbasins with US Forest Service land within them.
        - Subbasins in the States within the Region that do not have US Forest Service land do not get extracted.
    - Extracted NHD data are stored at a USDA-managed Data Center. The facility is managed by the USDA and USFS manages the servers with Forest Service data.
    - Forests use ArcGIS to access NHD at this Data Center through a Citrix application on Desktop computers. Employees use a virtual private network (VPN) to connect when not on the Forest Service network.
    - Data can also be viewed via a Web Map Service in a browser. However, performance and utility are poor.

- **Uses of NHD:**
    - NHD is used in conjunction with national applications for watershed improvement and aquatic resources databases. These applications allow Forest Service staff to input program proposals and inventory objects. The locations depend on NHD spatial data.
    - USFS creates events using the HEM tool: Aquatic biota inventories, stream crossing inventories.
    - These events reference NHD locations but are not reported to the USGS and are stored as local events.
    - NHD linework is used for the updating of Forest Service topo maps (FSTopo)
    - NHD linework is also used for Forest Visitor Map. This map will become interactive soon and therefore scale will become more important.
    - The most urgent needs for hydrography mapping for the Superior National Forests are for FSTopo Map updates (Late 2014) and the Interactive Visitor Map (2015).
    - Forest Plan revision for the Superior National Forest is a multi-year project that will begin in FY15. There are Monitoring and Implementation business needs that require hydrography as identified in the current Forest Plan. The protocols using hydrography will likely be revised in the next management plan. Any edits to the hydrography data need to be completed before the analysis phase.

- **NHD Stewardship:**
    - USFS Forests are becoming active co-stewards of the NHD that reside on or near Forest Service land.
    - Forests in Region 9 have signed agreements with many state stewards to edit NHD and participate in State NHD Stewardship processes. This means working with the designated state steward as an approved sub-steward, and coordinating updates with state entities.
    - Stewardship agreements are a prerequisite for National Forests to editing NHD.
    - Stewardship agreements have only been signed with States that have an agreement with USGS.
    - Stewardship agreements are also generally a prerequisite to participate in official USGS NHD Update Tool training.
        - Region 9 personnel participated in three NHD Update Tool training sessions in the Spring of 2014.
        - Representatives from the Superior and Chippewa National Forests successfully completed the required two part training.

Minnesota USGS Staff – Chippewa and Superior National Forests

USFS staff representing the Minnesota's Chippewa and Superior National Forests provided additional information specific to those areas. This included specific business needs and a description of the types of edits that they would expect to perform as part of the NHD Stewardship Program.

- **NHD Stewardship:** Staff at SNF and CNF successfully completed the USGS NHD Update Tool training in Spring 2014 and are poised to become active editors of the NHD.

- **Editing Needs:** Generally, the Chippewa National Forest and Superior National Forest have similar editing needs, which include:

    - *Connecting disconnected stream networks, where appropriate:* Disconnected stream networks could legitimately be connected in many locations. Making these connections would enable USFS to do better flow analysis.

    - *Modifying lake polygons by incorporating islands:* Many islands are missing from the delineations of lakes in northern Minnesota.

    - *Updating delineations where impoundments have been restored and returned to former land conditions:* These recent land restorations in the Chippewa National Forest are not reflected in the NHD.

    - *Correcting NHD Waterbody feature types*: Some areas of wetland have been miscoded as NHDWaterbody Lake/Pond features.

    - *Re-aligning waterbody shapes with imagery:* NHDWaterbody shapes need alignment with imagery to not overlap or distance mapped features with waters, i.e., roads, trails, campgrounds. This may be minor editing but it is important to USFS to be able to easily create their cartography which includes both hydrography and man-made recreational features.

- *Correcting GNIS names:* There needs to be some minor editing relating to GNIS names in the National Forests.

References

Personal/written communication with Susanne Maeder, MNGeo (2014): USFS staff representing the Eastern Region (Region 9, which includes Minnesota) provided information on regional use of the NHD and planned stewardship activity.

Personal/written communication with Susanne Maeder, MNGeo (2014): USFS staff representing the Minnesota's Chippewa and Superior National Forests provided additional information specific to those areas, including specific business needs and expected edits under a NHD Stewardship Program.

Chapter 3: Differences between the NHD and DNR Datasets

Objective

This chapter describes the basic geographic and attribution differences found between the geospatial hydrography datasets of the DNR and NHD. It compares the geometry, names and types of stream and lake data found in four selected DNR Major (USGS HUC-8) watersheds that represent the hydrographic diversity of Minnesota. The comparison results will be used to help specify how to synchronize both datasets with each other (*see Chapters 4-5*).

Summary

- Although nearly none of the NHD and DNR stream lines representing the same watercourse were found to be exactly coincident, the lateral distances between most of them were less than a foot which is significantly less than the width of most streams delineated by these data.
- In one HUC-8 (DNR Major), watershed lateral distances between stream lines were found to be significantly greater than the other three HUC-8s. The reasons were largely due to a unique hydrographic history for that watershed.
- Breaking down the lateral distances by stream type showed that, in many cases, those with the largest distances were so-called connector-type stream lines which, by definition, are somewhat arbitrarily digitized.
- Not surprisingly, DNR and NHD lake polygons were much more dissimilar than their respective stream lines. The polygons that make up DNR waterbodies are actually comprised of two different feature classes that fulfill different purposes: Public Waters basins (PW) and Open Water (OW) features. The NHD waterbodies are built from the original DNR 24K lake polygons, which were pre-cursors of the Public Water basins but are no longer used.
- Due to these dissimilarities, synchronizing lake polygons between NHD and DNR will be much more difficult than synchronizing the stream lines and will likely require more research. One of the DNR feature classes (either PW or OW) will need to be chosen as the source features for NHD waterbodies.
- Edits to the DNR hydrographic data due to new 2014 NWI data may produce even greater differences with NHD hydrographic data than indicated here. In addition, updates based on lidar data may also result in significant changes.

Procedural Details & Analysis

Preliminary Analysis

Stream Geometry

Early in February 2014, the DNR streams and NHDFlowlines[i] in the Wild Rice River watershed (DNR Major 60 or USGS: Eastern Wild Rice, HUC-8: 09020108) were analyzed by primarily comparing lengths, starting and ending points and attributes of respective lines in each dataset. On first inspection, the lines of both datasets appeared very similar. However, at larger scales, many differences in length- on the order of 0.01 to 0.001 feet- were found between lines that represented the same stream. This was likely due to the NHD data having been projected from its original Latitude/Longitude to the GDRS standard UTM coordinate system. The respective line endpoints were also offset by these distances.

Comparing certain aspects of the geometry of these two datasets (e.g., length), is confounded by a key difference in design. The DNR streams data generally treats stream reaches as all along a named river or creek. Stream attributes that vary along the length of these reaches are handled as associated “events”. Whereas the NHDFlowline data model divides reaches up into separate GIS features based on changes in stream type. As a result, a single DNR stream feature might be composed of several NHDFlowline features. Furthermore, grouping NHD features by Reach ID or GNIS ID does not provide a reliably consistent match to the DNR stream feature.

Lake Geometry

DNR waterbodies are comprised of two feature classes: Public Water and Open Water polygons. By law, the former includes the lake along with its wetland fringe up to what is known as the Ordinary High Water Level (OHWL). The latter includes the visible and/or interpreted exposed water component of the basin as identified on aerial photography.

The NHD waterbody polygons were based on the original DNR 24K lakes polygons which were derived from a combination of NWI open water and fringe wetlands categories. Over time, as both the DNR and NHD lake datasets were modified in separate edit cycles, their differences increased and the two datasets diverged significantly (*Figure 3-1*).

(For a more detailed description of the NHD and DNR hydrography datasets please see *Chapter 1*.)

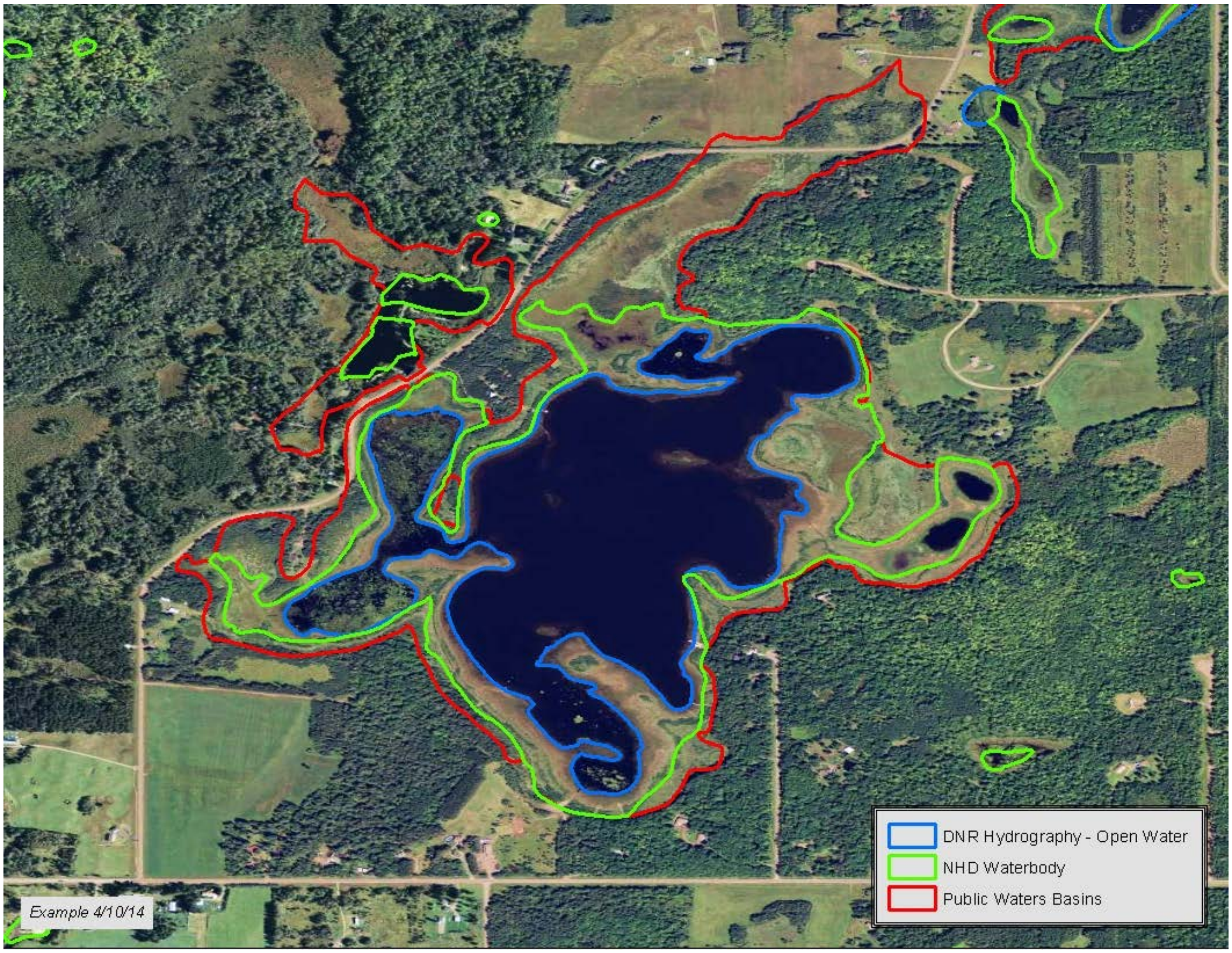
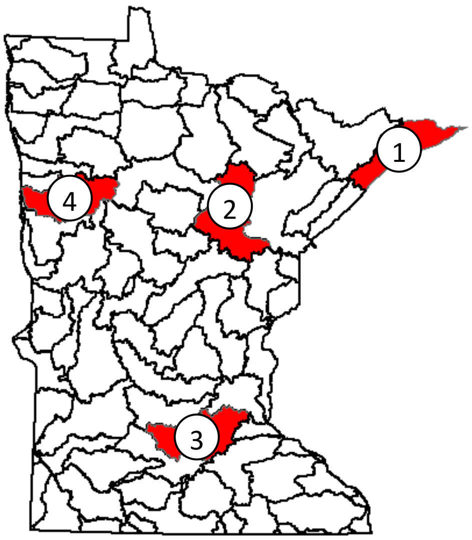


Figure 3-1. *Open Water, NHD Waterbody and Public Waters Basin for the same lake*

Comparison Methodology

The following methodology was conducted on four different USGS HUC-8 (DNR Major) watersheds representative of the state's diverse hydrography (*Figure 3-2*).



Map Number	USGS Name	USGS HUC-8	DNR Major Name	DNR Major Number
1	Baptism-Brule	04010101	Lake Superior-North	01
2	Prairie-Willow	07010103	Mississippi River – Grand Rapids	09
3	Lower-Minnesota	07020012	Lower Minnesota River	33
4	Eastern Wild Rice	09020108	Wild Rice River	60

Figure 3-2. *Map of four test watersheds and table of their USGS and DNR watershed names and numbers*

Stream Geometry

Summary: This procedure sought to address some of the concerns brought up by the preliminary analysis and create a process to quantify the differences between the NHD and DNR stream datasets. Multi-ring buffering was used on each dataset's linear features which were, in turn, overlaid on the other dataset's lines. Essentially, this method finds the lateral distance between respective stream lines as well as those features found in one dataset but not the other. It can also be used to find the correlation of stream types between datasets.

Detail: To minimize the many-to-one relationship between NHD flowlines and DNR streams (as described in the preliminary analysis) both stream datasets were first dissolved (merged) into single features and then split at their three-way (or more) confluences (*Figures 3-3 & 3-4*).

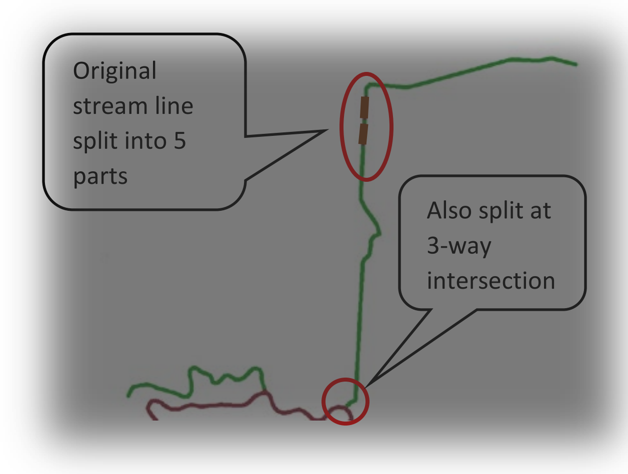


Figure 3-3. Stream lines before Dissolve

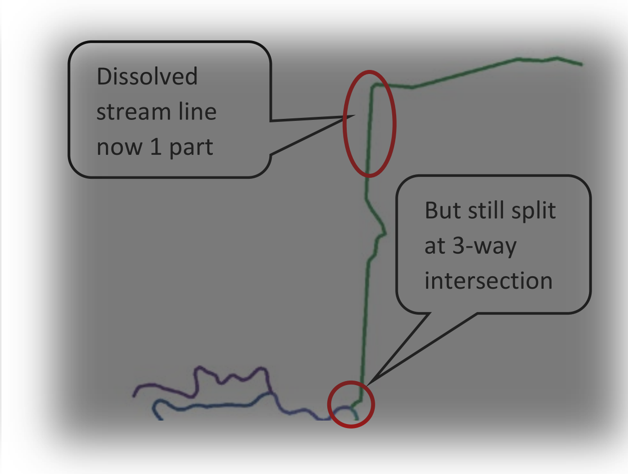


Figure 3-4. Stream lines after Dissolve

After dissolving, a multi-ring buffering operation created several concentric buffer polygons around each stream line at predetermined distances. Then an ArcGIS Identity operation was run to split the overlying stream lines of the other dataset by each buffer (e.g., DNR streams split by NHD flowline buffers).

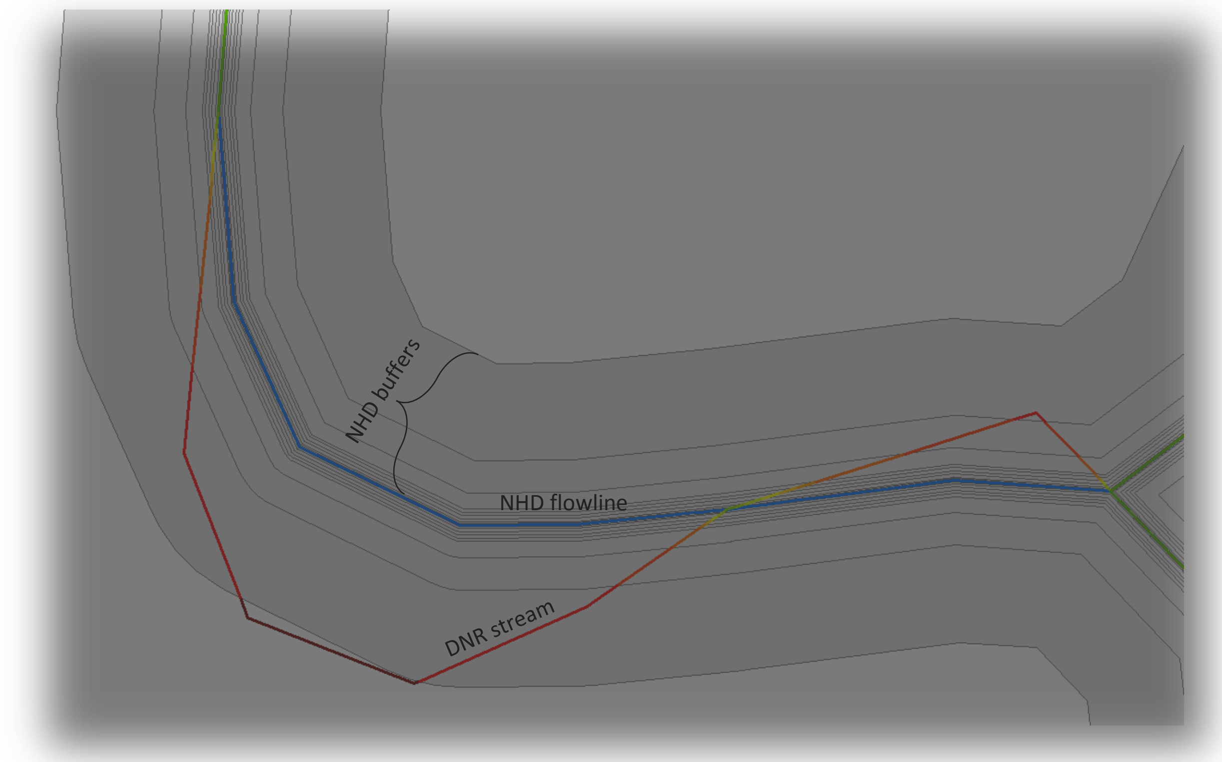


Figure 3-5. *Overlay of DNR stream (multi-colored line) on NHD flowline (blue line) with NHD buffers (gray areas)*

Figure 3-5 illustrates the output of the multi-ring buffer-identity operation. The multi-colored lines represent DNR streams while the blue lines and gray areas represent the NHD flowlines and their respective buffers. Note that while the DNR streams are coincident at either end with the NHDFlowlines they diverge significantly around the bend in the lower left where their distances from them range from 0 (green) to greater than 50 feet (dark red). The lengths of the lines within each buffer were totaled per watershed to produce a summary indication of overall stream offset (lateral distance).

To find stream lines missing from either dataset, the above method was run twice: first, where NHD lines were overlaid on DNR buffers and second, where DNR lines were overlaid on NHD buffers. Those stream lines in either dataset which were greater than 50 feet from streams in the other dataset were often missing in the latter dataset.

Stream Type

A similar process to comparing stream geometry was used to compare stream lines by type. The main difference was that instead of dissolving each dataset's stream lines by three-way (or more) confluences, they were dissolved by their type. For NHD, the stream type is designated by the FType (feature type) field, while for DNR features, the STRM_TYPE field designates the stream type (*Table 3-1*).

	NHD		DNR	
Group #	**FType**	**Description**	**STRM_TYPE**	**Description (STRM_LONG)**
1	334	Connector	61	Connector (Wetland)
			81	Arbitrary Flow Connector
2	336	Canal/Ditch	40	Drainage Ditch (Perennial)
			41	Drainage Ditch (Intermittent)
			42	Drainage Ditch (Undifferentiated)
3	428	Pipeline	71	Underground Storm Sewer
4	460	Stream/River	20	Stream (Perennial)
			21	Stream (Intermittent)
			22	Stream (Unknown)
	558	Artificial Path (not within Waterbody)	62	Centerline (River)
			63	Connector (River)
			80	Interpreted Arc Connector
			90	Superceded [sic] Natural Channel
5	558	Artificial Path (not within NHDArea)	60	Connector (Lake)

Table 3-1. *Associated Stream Types between NHD and DNR datasets*

Each group within Table 3-1 represents comparable NHD and DNR stream types. Multi-ring buffers and identity operations were run on each of the groups for each HUC-8. Once again, the lengths of the lines within each buffer were summed to produce an overall indication of stream offset (lateral distance) per type.

Lake Geometry & Name Comparison

To compare DNR open water[ii] and NHDWaterbody geometry and names, a basic ArcGIS Union operation was performed. This produced a single output feature class for each HUC-8, containing polygons that represented areas where the two datasets' polygons overlapped as well as those areas where only one dataset's polygons existed. In the former case, the attributes from both datasets' polygons were found in the output polygon. In the latter, attributes from only the existing dataset's polygon were found.

This permitted a relatively easy way to find the coincidence of lake polygons, both regarding their geometry and their name attribution.

Results

Stream Geometry and Type

Stream Geometry Comparison for three of the HUC-8s

Although the preliminary analysis showed that almost none of the stream lines from DNR were exactly coincident with those of NHD (for 07010103, 07020012 and 09020108), this comparison revealed that, laterally, ~90% were within 0.1 feet of each other. This is significantly less than the width of most streams delineated by either dataset and even less than the best resolution (6 inches) of current aerial photography. Only ~ 5% of NHD streams were > 50 feet apart or missing from either the DNR or NHD stream line data in these HUC-8s.

Stream Type Comparison for three of the HUC-8s

As might be expected, this comparison (for 07010103, 07020012 and 09020108) revealed more significant differences between DNR and NHD stream data than the stream geometry comparison. Results also showed that the differences varied by type. For these watersheds, ~90% of Group 4 (stream-river) type stream lines were within 0.1 feet of each other. On average, 7.8% of this type were >50 feet apart or missing from either the DNR or NHD stream line data.

Group 2 (drainage ditch) type stream lines were not quite as close, ranging from 83% to 92% within 0.1 feet of each other. Those stream lines of this type >50 feet apart or missing from either NHD or DNR data ranged from 6% to 11%.

Those stream types furthest apart were from Group 1 (non-lake connector) and Group 5 (lake connector). As these types do not delineate actual features on the landscape, and are therefore somewhat arbitrarily digitized, it is not surprising that they were furthest apart. They also varied the most in the 0.1 foot category, from 12% to 55%. Those stream lines in the > 50 foot or missing category also varied greatly, from 41% to 87%.

Stream Geometry and Type Comparisons for HUC-8 04010101

The comparison results for this watershed were not consistent with those from the other three. Only 54% of the stream lines were within 0.1 feet of each other, whereas 27% were ≥ 50 feet away or missing from either the DNR or NHD stream line data.

Interestingly, the numbers for Group 1 (non-lake connector) and Group 5 (lake connector) type streams were roughly similar to those of the other three watersheds. Group 1 ranged from 28% to 45% within 0.1 feet, and 45% to 65% that were ≥ 50 feet apart or missing from either the DNR or NHD stream line data.

Those in Group 4 (stream-river) departed from the same type in the other three watersheds much more significantly. Only about 55% of these Group 4 type stream lines were within 0.1 feet of each other. Approximately 28% of this type were ≥ 50 feet away or missing from either the DNR or NHD stream line data.

The hydrographic history of this HUC-8 offers an explanation for some of the differences. Many of the streams and rivers along the North Shore of Minnesota that flow into Lake Superior are ideal trout habitat and therefore subject to DNR regulation and monitoring. Some of these streams were re-digitized by the DNR using more accurate reference data (e.g., aerial photography) than was available when the NHD features were digitized. Figure 3-6 illustrates this. Note how the newer DNR stream line (blue) more accurately follows the 2010 FSA photo image of the river than does the NHD stream line (red).

Figure 3-6. *NHD flowline (red) v DNR stream line (blue) over 2010 FSA photo*

Yet, in 2009, as a test of the new USGS conflation tool, four HUC-10s were conflated by MnGeo from the older NHD to newer DNR stream lines (0401010101, 0401010102, 0401010108 and 0401010110). During this process, NHD stream lines were replaced by those from the DNR but the attributes of the NHD were conflated (retained) back to the new lines. In these four HUC-10s, the lateral distance between the DNR and NHD lines are therefore minimal.

Finally, the NHD stream lines that lie near the border with Ontario, Canada have undergone changes related to border water harmonization. This was an effort by both countries to join and make consistent their respective stream line datasets (and consequently their common watershed boundaries) along the international boundary. The DNR's jurisdiction, of course, stops at the national boundary and therefore their stream lines and watershed boundaries do not extend beyond it. In some cases, however, the NHD stream lines and watershed boundaries do cross the international boundary and therefore are inconsistent with those from the DNR.

Lake Geometry & Name Comparison

The percentage of lake polygon area that overlapped between the NHD and DNR datasets varied from 31% to 44% among the four HUC-8s. Where overlap percentages were low, features were often missing from one of the datasets. For those polygons that overlapped, from 9% to 39% had the same name. In addition, while the NHD data generally had many more lake polygons in each HUC-8 (average = 1413 more), the DNR lake polygons had more overall area (average=1,801,748 acres more). Note that these differences are due to the different origins and histories of the two lake polygon datasets (*see Chapter 1*).

(For tables showing all the detailed comparison results, see *Appendix 3b*.)

Conclusion

These comparison tests show that the geometric differences between the stream datasets were small and even trivial in some cases. However, for stream types, lake geometries and lake types the differences were more significant. The types of differences varied by test HUC-8, indicating regional variations in the data. In the near future, the DNR will update their hydrographic polygon data to coincide with new NWI and/or LiDAR data available in 2014. This may result in significant changes to the DNR data, which would produce even greater differences with the current NHD data than found in this chapter.

References

Appendix 3a: Differences between the NHD and DNR Datasets (Buffer Analysis Methods) – Quantifying Differences between DNR & NHD Hydrography Data – *describes actual processes run in Chapter 3*

Appendix 3b: Differences between the NHD and DNR Datasets (Buffer Analysis Methods) – Excel spreadsheet of results from Difference Testing – *describes results from testing in Chapter 3*

Appendix 3c: Difference Testing Notes - DNR Hydrography vs. NHD: A DNR comparison in DNR Major #60 – DNR Hydrography vs. NHD: A comparison by watershed (60) – *draft notes from preliminary DNR testing by Lyn Bergquist, 2/6/14*

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[i] The DNR streams feature class was *DNR Stream routes with Kittle Numbers and Mile Measures*. Both DNR and NHD feature classes were loaded from the GDRS' Quick Layers tool into ArcMap.

[ii] The DNR open water feature class used was *DNR Hydrography – Water Features.* Both this feature class and the NHDWaterbody feature class were loaded into ArcMap from the GDRS.

Chapter 4: DNR-NHD Data Synchronization

Objective

This chapter focuses on data considerations, tools, rules and processes for re-synchronizing the DNR Hydrography and NHD datasets. *Chapter 5* describes a 2009 pilot test of the USGS Conflation Tool for synchronization of DNR data to NHD, and outlines changes to that process based on the procedures outlined for future data synchronization, as described in this chapter.

Summary

- The NHD Conflation Tool is the recommended tool for the DNR-NHD Data Synchronization
- DNR datasets have been identified for most of the inputs to NHD:
  - **dnr_rivers_and_streams** to **NHDFlowline**
  - **DNR Hydrography Open Water** (most feature types) to **NHDWaterbody**
  - **DNR Hydrography Open Water** (selected feature types) to **NHDArea**
  - **NHDLine** and **NHDPoint** have no corresponding DNR input and need to be treated differently
- Synchronization is a two-way, not one-way, process
- A multi-step process has been defined to Synchronize the two data sets
- A data comparison needs to be performed first to identify features for which the NHD representation is better. Those features are copied to an "Exceptions" file (They are Exceptions to the rule that DNR current input features will be used)
- DNR datasets are edited to incorporate the "Exceptions" identified in the data review
- Edited DNR data is converted to resemble an NHD dataset preparatory to Conflation
- QC work is done on the data prior to conflation. Once a dataset enters the conflation process there is no opportunity to edit it
- Edited DNR data in NHD Format become the input delineations upon which the NHD attributes are conflated – the output NHD dataset has DNR linework
- There are unresolved issues for conflation of DNR to NHD, including streams in headwaters lakes and 1-d stream delineations at state borders
- There are unresolved issues that may not pose a problem for a conflation from DNR to NHD but are a stumbling-block to a DNR's direct use of an NHD base:
  - Representations of islands as their own feature type in the lakes dataset
  - PW Basin representations (PW Basin boundaries are boundaries defined by state law and maintained by DNR)
  - Stream flowlines at the border need to be considered

Procedural Details & Analysis

Overview and Tools

Overview

When the high-resolution (1:24,000) NHD was originally built for Minnesota (2002-2005), the DNR 24K streams and DNR 24K lakes layers formed the base flowline and waterbody features for high-resolution NHD over much of the state. (Exceptions were northwestern and southeastern Minnesota, and, in particular, HUC's that straddled the state border). Because of the original production process, Minnesota's high-resolution NHD and the then-current DNR 24K hydrography base were largely synchronized. Since that time, the two datasets have diverged in both geometry and attributes.

Reasons that the DNR Hydrography and NHD datasets have diverged include:

- Edits were made to the NHD database – by the state and USGS– in most cases without reference to changes made on the DNR dataset.
- DNR consolidated streams edits from three different internal efforts (i.e., original MNDOT Basemap 24K streams layer, Lake Watershed Delineation Project, Fisheries trout stream edits) into a single streams feature class, using the best available line features as the new DNR Hydrography stream features.
- DNR continued development of its Public Waters (PW) basins and re-delineation of Open Water (OW) basins datasets and discontinued maintenance of the original DNR 24K lakes dataset. In 2012, the updated PW and OW basins layers became the core basin feature classes within the new DNR Hydrography dataset, replacing the older DNR 24K and DNR 100K Hydrography layers.

In an effort to create a single, authoritative spatial hydrography dataset for the state of Minnesota and to streamline the future maintenance processes, there is a need to fully re-synchronize the two datasets. Furthermore, a more streamlined state and federal update process must be developed that meets the needs of multiple stakeholders going forward.

This chapter details the methodology for re-synchronizing the DNR Hydrography and NHD datasets. The material focuses on data considerations, tools, rules and processes for synchronization, including required data inputs. *Chapter 5* outlines the **Conflation** process for synchronization that was performed in a 2009 pilot test by MnGeo. *Chapters 6-7* describe three possible options for maintaining the synchronized dataset(s) moving forward.

Tools for Updating the NHD (NHD Update and NHD Conflation Tools)

In support of its NHD Stewardship program, USGS has developed tools that enable updating of the NHD by two methods. Both are ArcGIS-based desktop editing tools that work on a personal or file geodatabase.

The ***NHD Update Tool***[i] is used to add, update or delete features individually and en masse. It enables the attribution of global unique identifiers, feature types, reach codes (from the federal database) and geographic names (from **GNIS**). It also applies topology rules and performs numerous data checks before the updates are cleared to be passed back to the federal USGS NHD database. This tool can be used to make a small number of edits or for more extensive editing (for instance, revision of selected features based on newer imagery). It is generally not used to do a mass replacement of features, however.

The ***NHD Conflation*** tools are used to perform a global replacement of underlying features and then apply the existing NHD attributes to the new features. A set of topology rules and QA checks are subsequently applied to create a new version of NHD. This toolset has been used in some smaller areas (although not in Minnesota) to replace the existing NHD stream network with a new **LiDAR**-derived network. The NHD Conflation Tools would be the recommended toolset for the DNR-to-NHD synchronization process, since a large number of features would have to be changed to bring the data sets back into sync. The volume of features that would need replacement in order to re-synchronize the two datasets makes the NHD Update Tool unfeasible for this effort. Once the data are re-synchronized, future updates from DNR to NHD could be performed using the NHD Update tools, since the number of edits should be much smaller.

Note that, when using a completely new set of base features such as the revised DNR delineations, there is an option to assign a totally new set of reach codes (i.e., not conflating the existing reach codes). This option will not be chosen because we need to preserve as many existing reach codes as possible. Organizations such as USGS, USFS, and MPCA have created event datasets based on the existing reach codes. Changing all of the reach codes would create significant maintenance problems for these agencies.

Data Input Specifications for the NHD Conflation Tools

- The "input" data includes the lines and polygons that will replace current NHDFlowline, NHDArea and NHDWaterbody features. Data preparation is the most time-consuming part of this process. This data must conform to the NHD data format as described in *Chapter 1*. The conflation documentation recommends that some QA/QC and flow-check steps be performed before the tool is run to help ensure accurate formatting. Once the conflation processes start, there is no opportunity to edit the input data.
- The "to-be-conflated" data is NHD federal data extracted from USGS in a geodatabase format. This becomes the base for reach codes, GNIS names and other NHD attributes that will be applied to the input features.
- The "output" data is the "new" NHD dataset, consisting of the new input lines, the conflated NHD attributes, and any corrections or updates that need to be made to the attributes.
- The NHD Conflation Tools require an "input" set of delineations that complies with NHD format specifications: 1-d streams (linear features), 2-d areas for streams (polygons), lake (and possibly) wetland polygons, all integrated prior to conflation. NHDPoint and NHDLine features also need to be accounted for.

    - **NHDFlowline input**:
        - 1-d streams need to have nodes at confluences and where entering and leaving waterbody polygons. Waterbodies need to have nodes where they intersect streams. This is so that stream features can be snapped to boundaries of waterbody features at inflow and outflow points.

- 1-d streams need connectivity with other stream and waterbody features (where appropriate) and directionality representing flow direction.
- NHD flowlines need to be coded with stream types (Ftypes). Some stream types (e.g., stream/river or canal/ditch) will already be defined on the input 1-d features. Others are created by the intersection with the 2-d area and waterbody features to assign stream types such as "artificial path" and "connector" to streams which run through polygons. If all input data is from DNR sources, then these will stay synchronized with the DNR feature types.

- **NHDArea (2-d stream) Input:**
  - Input data is intersected with 1-d streams to determine the stream feature type of "artificial path". Topology rule: 1-d feature must be inside 2-d feature for the extent of a single 2-d area polygon.
- **NHDWaterbody Input:**
  - All required NHDWaterbody features (of Ftypes such as lake/pond or swamp/marsh or reservoir) need to be in the input data set.
- **NHDPoint and NHDLine feature classes:**
  - If not updating these features, an empty feature class for each of these must exist in the input dataset to complete the model.
  - If Minnesota did choose to edit these at a later time (for instance, importing the Minnesota springs database into the NHDPoint feature class), it could be done using the NHD Update Tool.
  - Minnesota had intended NOT to update these features since there is no matching local source. However, USGS has recommended that the existing NHDLine features need at least to be compared to the new input features to make sure they are not misaligned.

Synchronization

Synchronization Process Issues: One-Way versus Two-Way Editing

At the outset of this project, the project team had assumed a one-way update process, using features updated in the DNR dataset to update the NHD. MnGeo, working with MPCA and DNR in conflation testing (2009) and also in a more extensive data comparison (2010), found that the updating may not always be one way. In most areas, DNR had improved linework over NHD. However, in some areas, NHD data had been improved where DNR data had not. Because we all want the best feature representation available, the process had to be modified from the original proposal.

The revised concept assumes that the DNR data is generally the "best representation", but that all data would have to be scrutinized to identify exceptions to this rule. In cases where the current NHD had improved data, or in which neither dataset seemed to match current imagery, other layers would be consulted to identify the best delineation for a feature. In order to simplify the NHD conflation process, changes (found by this exceptions process) would first be made to the DNR hydrography dataset to reflect the best available linework, then this revised linework would become the input to the NHD conflation process. This process would involve a lot of interagency consultation, and would be performed on one HUC-8 (DNR Major Watershed) at a time.

DNR-NHD Data Synchronization Process Steps

Figure 4-1 illustrates the DNR-NHD Data Synchronization Process. The synchronization process will include the following steps:

- *(1) Data review*: Input layers for the conflation process are assumed to be the **dnr_rivers_and_streams** for the ***NHDFlowline*** feature class, the **DNR Open Water** for the ***NHDWaterbody*** feature class, and **DNR Open Water** "riverine" and "inundation area" features for the ***NHDArea*** feature class. Comparison features would be the current ***NHDFlowline***, **NHDArea**, and **NHDWaterbody**. Input rules assume that DNR features are the default "best available" features. The data review would identify any areas where feature representations in the two data sets do not match (*Chapter 3*), and identify which feature representation is correct. Background data sets such as imagery, LiDAR, and other hydrography layers (including DNR PW Basins) would be used to help determine which feature delineation is correct.
    - If the DNR feature is correct, then nothing needs to happen, as that is the presumed input dataset.
    - If the NHD feature is correct, the feature would be identified and copied to an "exceptions" database.
    - The "exceptions" database must contain one feature class for linear features (to update the DNR streams dataset) and one for polygon features (to update the DNR OW dataset).
    - If neither representation matches current imagery, re-digitization could be done to create a correct representation, which could then go into the "exceptions" file.

- *(2) DNR Hydrography Dataset edits:* features in the "exceptions" datasets would be used to update the **dnr_rivers_and_streams** and **DNR Open Water** feature classes with improved delineations. Updates to the **DNR Open Water** features would be constrained by topological relationships with the PW Basin features.

- *(3) Create Input Data Set for NHD Conflation:*
    - Apply the formatting rules to the DNR data inputs to create a "quasi-NHD" dataset.
        - NHDFlowlines with directionality, connectivity, feature type codes, nodes in correct places
        - NHDWaterbodies with feature type codes, nodes where intersecting streams
        - NHDAreas with 1-d flowlines inside 2-d areas where appropriate
        - Existing NHDLine features need to be compared with new input features. Any NHDLine feature that now mismatch must be edited.
    - Apply pre-conflation checks.
    - Check out a current version of the NHD to obtain the attributes needed for conflation.

- (4) *Run NHD Conflation Tools* on this input data set, creating as an output a revised version of the NHD for this HUC-8

- (5) *Check edited NHD* (output version) back into the National NHD Database
- (6) *Obtain new NHD state extract* and distribute to state GDRS
- (7) *Create DNR derived products* from results of step 2 and distribute to GDRS

The Step 1 "Data Review" will require interagency consultation and review. Since we want to capture the "best available" features, all concerned organizations (i.e., MnGeo, DNR, MPCA, USFS where appropriate, maybe USGS Point of Contact if there are questions) may need to review the proposed input data, including the flagged "exceptions". Organizations will need to come to an agreement on which input lines to use. Agreement up front on the best input lines will result in better buy-in on the dataset as a whole.

Editing Considerations

Border Issues

- *State-to-State border issues:*
  - Artificial Path Flowlines outside of state border:
    - A state dataset (such as DNR) can maintain its flowlines all within a state border.
    - A national data set (such as NHD) will maintain a single river main stem flowline through a 2-d feature in a HUC-8, where that 2-d feature defines a state border (e.g., main 1-d path of the Mississippi River below Hastings, MN).
    - Where the state border is defined by a 2-d river, the "true" border is a theoretical line (i.e., center of the main flowpath at the time of statehood) that is approximated on most maps and GIS datasets. The artificial path flowline may be arbitrary or, at best, represent a main navigation channel which may cross the state border. For compilation purposes, both states like to have the artificial path flowline inside state borders, but these features meander across borders.

- *US-Canada border issues:*
  - Only the Binational Editing Team can edit NHD features at the US-Canada border. If the state were to do wholesale conflation to create a new database, that team would probably have to review the border features before incorporating into the NHD. Then it would have to be re-seamed with Canadian data by the Bi-National Editing Team.
  - Artificial Path Flowlines outside of the US: at the US border there are two sets of flowlines – one on the US side and one on the Canada side.

NHD Feature Classes that cannot be updated from the DNR Hydrography Data

- The feature class **NHDLine** includes dams, levees, bridges, waterfalls, and other linear features that do not participate in the drainage network. This feature class largely represents what appears on USGS topographic quad maps, but is not a complete listing of all available features.
- The feature class **NHDPoint** includes some wells and stream gages, rocks, etc., but is also not complete. USGS stream gages and dams in the National Inventory of Dams have been re-entered as NHD point events, hydrologically referenced to the NHD flowlines. The NHD points of wells or springs are small subsets of what actually exist, and there would be a state dataset that could provide that information.
- We would choose NOT to update the **NHDPoint** feature class.
- The **NHDLine** feature class needs to be compared with the new input data (and possibly edited) because there may be a mismatch – for instance, a linear dam feature that no longer completely intersects the 2-d area stream that it impounds, or linear levee features along a 2-d stream that no longer match.

DNR data source for NHDWaterbody

Most NHD Waterbodies in Minnesota were originally derived from DNR 24K lakes, which were derived from Open Water and fringe wetland categories of the original National Wetlands Inventory (NWI). The original NWI for Minnesota was interpreted over the period 1991-1994, using source photography covering the period 1979-1988. DNR no longer uses the 24K lakes as a base layer in its new DNR Hydrography dataset, replacing it with the newer Open Water basins feature class. Furthermore, DNR currently maintains two separate but integrated basins layers (i.e., DNR Open Water and DNR Public Waters) to support two different business needs. The Public Waters Basins (PW) represent Ordinary High Water Level (OHWL) delineations with a regulatory function for permitting activities. DNR Open Water delineations, on the other hand, follow the open water as visible on aerial photos and are used to generate numerous derived product layers for fisheries management and other purposes. These layers hold two different geometric representations of the same named feature, identified by the DNR Lake ID (i.e., DOWLKNUM).

Over time, edits have been made to the NHD Waterbodies. Also, DNR has changed its base waterbody features. Therefore, in many cases NHD Waterbodies no longer match the DNR Open Water or Public Waters Basins. **This is the most significant data synchronization issue**. Since the NHDWaterbody delineations are expected to change significantly during re-synchronization, this is a major maintenance issue for the MPCA, which has created numerous polygon events on the NHD Waterbodies.

The pros and cons of using each layer as the basis for a new NHDWaterbody layer are outlined below; the decision is summarized at the end.

PW Basins

A Public Waters (PW) Basin is the “container” for the water of a lake, pond or wetland based on a determination of its OHWL. The list of PW Basins and their boundaries are established by Minnesota Statute and information about them is maintained by DNR Waters. Often the delineation represents both open water and the fringe wetlands that make up the OHWL container. DNR maintains a feature class that includes delineations of 21,960 Public Waters Basins in the state, with a code that indicates the public water class. Note that, in many cases, the PW Basin polygon and the DNR Open Water polygon are represented by the same delineation.

- *PW Basins – Pro*
    - Because it maps the container and not just open water, the boundary tends to be more permanent on the landscape, not changing from year to year and season to season depending on hydrologic events.
    - Because it maps the container defined by OHWL, it may be possible in the future to update boundaries based on LiDAR elevations.
    - Because the PW Basin polygon must be at least as large as the open water polygon, it is possible to create the Fisheries Open Water polygon as an "event" on the PW Basin using USGS Hydrography Event Management (HEM) tools.
- *PW Basins – Con*
    - Some PW Basins (including one or more open water polygons surrounded by wetlands) may be very large, may not match the lake outline on most maps, and may cross roads. Some of these polygons are not acceptable as single NHD Waterbodies.
    - The PW Basin is a *regulatory* boundary for DNR, so that they do not want other organizations editing those boundaries. The fact that PW Basins is a legal rather than a hydrologic boundary may make it inappropriate to use for NHD.
    - When adding missing waterbody features to NHD, MPCA generally uses an open water representation rather than the PW Basins representation.
    - The PW Basins feature class does not include many small lake polygons currently in the NHD. Because we want to include as many small lake features as are reasonable to accurately represent the water on the landscape, PW Basins may be insufficient to represent the waterbody base of NHD.

DNR Hydrography Open Water
Fisheries has an ecological and management basis for using the "Open Water" (OW) portion of a PW Basin. The Open Water can be coincident with the PW Basin or can be smaller, but will not (except under extraordinary high-water conditions) be larger. An extensive editing process is underway to integrate the two datasets, which should be fully integrated by the time that we are ready to perform statewide NHD-DNR waterbody synchronization.   The DNR Hydrography Open Water layer also includes island polygons, but these are coded as such and can be removed from the database before it is used to create the NHD Waterbody.   <u>DNR has a need for the island features. If there is not a place for them in NHD, then that is another issue for synchronization. Using the PW Basins as the source instead would present the same issue for DNR</u>.

- *DNR Hydrography Open Water – Pro*
    - Not tied to a state legal process, so that if another agency wants to edit an Open Water polygon to better match newer imagery, if would not cause DNR a lot of problems. (However, DNR Fisheries is still concerned about other organizations editing these features and would need to review proposed changes. There may be a percent change in size threshold for edits that could be done without review.)

- Often a better representation of how the lake looks on the map. On a topo map it would be outlined and named as a blue open water polygon, with adjacent wetlands hashed in with the wetlands pattern.
- Would not have issues of a larger wetland polygon crossing roads.

- *DNR Hydrography Open Water – Con*
  - Because it is the smaller polygon, it is not possible to create a "Public Waters" event polygon on an NHDWaterbody polygon that was created from Open Water. **This requires DNR to maintain a Public Waters basins feature class outside of NHD.** This is a significant roadblock to achieving a single, statewide spatial hydrography dataset that meets all business needs.
  - The open water extent changes more frequently – seasonally and by year – possibly prompting more dissatisfaction with the representation and more need to edit it. (As a point of policy, we probably want to ID spring leaf-off imagery as the source for a delineation update, since the open water would be at its greatest extent, and may shrink over the summer months.)
  - Although we have to leave the administration of the PW basins data entirely to the DNR, if they want to keep the rule that NWI encompasses PW which encompasses DNR Hydrography Open Water – then OW still cannot be edited (whether in Fisheries environment or NHDWaterbody environment) without reference to the extent of the PW Basin boundary.
  - The smaller polygons on DNR Hydrography Open Water were generally not re-digitized by DNR Fisheries but are from the USGS 100K DLG source hydrography. These features should be edited from newer sources (whether new NWI, current NHD, or imagery) at the DNR Hydrography OW level before conflation occurs. DNR is interested in the smaller polygon features as long as they are recognizable on new source data. (DNR would also be amenable to keeping features that MPCA added to NHD to delineate lakes or ponds that they sample.

Decision

Given the above comparisons, the decision has been made to use the **DNR Hydrography – Open Water** feature class as the input data. It usually has a better "open water" representation and appears more like the 1:24,000 topographic map that NHD tried to capture. Also, because it does not represent a legally-defined boundary, we don't have the editing constraints that we would have with PW Basins. (We would, however, still have to be cognizant of the PW boundary constraints when editing a waterbody).

How and when to include wetlands

Minnesota did not include wetlands (NHDWaterbody category Swamp/Marsh) in the NHD dataset because the NWI base was considered to be inaccurate in some areas. This was a decision rule recommended by DNR and accepted by the Minnesota-USGS-EPA team that developed the guidelines for the original high-resolution NHD production in Minnesota. This decision rule was not necessarily followed by other contractors developing high-resolution NHD, especially for HUC-8's that straddled the state border. For instance, the HUC-8's in the Red River Valley and portions of the Lower Rainy River drainage, as well as some HUC-8's in southeastern Minnesota, would have used the "blue lines" from the 1:24,000-scale topographic maps, and would have input wetlands.

Now that Minnesota is developing a revised NWI, we need to discuss whether to add wetlands in the synchronization phase. DNR Hydrography Dataset developers are talking about integrating the new NWI into their product, and USGS is talking about integrating NWI and NHD – although it is not clear exactly what that means.

Another issue is that, when MN NHD was created using the Minnesota-defined process, all DNR 24K lake polygons were brought over as NHDWaterbody feature type "Lake/Pond". Some are wetlands that really should be typed as "Swamp/Marsh". Some have had their attributes changed. Whichever dataset is used as the input for NHDWaterbody, we should use the feature type of "wetland" where it exists to better assign the NHD feature type.

Data Source for NHDArea

NHDAreas most often represent the 2-d areas where wider streams and rivers are depicted on a map with two banks. The purpose of these features is largely cartographic. There is a topology rule in NHD stating that the 1-d stream artificial path feature must be inside the 2-d stream feature where they clearly depict the same stretch of river. Since some MPCA and DNR management activities need to identify a buffer distance from a stream bank, these 2-d features can be important. NHD has capture rules for 2-d stream features prescribing which 2-d features are large enough to delineate. None of the existing potential input databases are perfect; any would involve some editing, and any change would require checking to make sure the 2-d feature still encompassed the 1-d feature. Because of this, there is no clear superior dataset to be used as the source data for 2-d features. The possible sources for this input data include:

- **Current NHD**

  For current Minnesota NHD, the source of the 2-d areas is the "riverine features" from DNR 24K lakes (derived from NWI) or else the blue lines from the topo maps. In the case of the former, these have been extensively edited in NHD to eliminate inconsistent features and numerous small "blob" features along 1-d streams. Because of the amount of editing that has been done on these features, this 2-d area data set may be the better one. However, if we used this one there would be more changes on the DNR side.

- **DNR Hydrography Open Water**

  Within this feature class, use features with **WB_Type** code = "riverine polygon" or code = "inundation area". Some of these riverine polygons have been re-digitized by DNR Fisheries (see attribute REDIG_SRC). If the REDIG_SRC code indicates that the riverine polygons are based on

1:100,000-scale DLG data, then the current NHDArea data probably provides a better representation.

- **DNR PW Basins**
  This feature class does not contain riverine features except for some Mississippi River (U.S. Lock & Dam) pools.

Decision

To be consistent, the decision was made to use the DNR Hydrography Open Water subset of feature classes to define 2-d area, but recognize that at the Data Review stage many features will be replaced by features from the existing NHDArea or new NWI where available.

NHD Stream Segments in Headwaters Lakes

The NHD Data Model requires that, for the purpose of maintaining connectivity, a stream connected to a headwater lake must be extended into the lake. DNR generally begins the stream at the headwater lake outflow. To make the 1-d streams datasets consistent, they would both need this feature. In the case of DNR, these stream segments could be coded so that they could be removed from calculations or derived products. However, if the delineations came from NHD (where it does not have a code that distinguishes it from other "artificial path" features) it would be more problematic to identify (e.g., an artificial path through a waterbody feature that flows out of the feature but does not flow in). It might be possible to identify all artificial paths, then reselect those whose from-node and to-node intersect with a polygon boundary then drop the rest, or use something like the DNR "fetch" tool to create the upstream portion.

The Impact of extensive change to NHDWaterbody features on MPCA

Changing the NHDWaterbody polygons would have the greatest impact on MPCA, since they have built thousands of Assessment Unit ID (AUID) events (using the DNR "DOW Lake Number" as the event identifier) on waterbody features for EPA Clean Water Act (Sections 303(d) and 305(b)) reporting. MPCA revises their AUID events biennially to meet the EPA reporting requirements. Full synchronization of NHD-DNR waterbody datasets would create significantly more work for MPCA in updating Lake AUID data sets for the affected biennium.

Summarizing Data

State agencies need to get the same results when summarizing NHD Flowlines and Waterbodies within Minnesota's border as compared to summarizing DNR streams and polygon hydrography features (excluding riverine features). If the datasets were synchronized, the results should be the same (except for minor rounding errors due to conversions.) Because NHD extends outside of state boundaries to include full HUC-8's, there is extra processing necessary to remove non-Minnesota features from the NHD summary; however, once set up as a model it should be repeatable. Summary of PW Basins polygons and DNR Open Water/NHDWaterbody lake-type polygons will be different, but explainable.

NHD Conflation Data Preparation: Data Input Rules

Data for comparison:

- Current **NHDFlowline**, **NHDArea**, **NHDWaterbody**
- DNR: **water_dnr_hydrography.gdb:**
  - o **dnr_rivers_and_streams (1-d), dnr_hydro_features_all (2-d)**
- Other DNR Hydrography:
  - o **PW Basins** (reference), **DNR Watersheds level 8 Catchments and level 4 (Major Watersheds**).
- Background ancillary data: imagery (esp new spring leaf-off), lidar, old and new NWI, Altered Watercourse (NHDUpdate flag = change geometry).

NHDFlowline (1-d stream feature in NHD):

- At its base, the 1-d stream geometry for DNR and NHD need to be the same line. Stream Type attributes need to be consistent. Node placement needs to be consistent. DNR can create a set of derived products from the basic linework.
- Use the DNR (water_dnr_hydrography.gdb)\feature class **dnr_rivers_and_streams** as the input data set
  - o Description: 1-d feature, nodes at intersections and where stream type changes.
  - o ***Appendix 4*** compares DNR **strm_type** with NHD **Fcode** and **Ftype**. The mapping between the two sets of features is reasonable but not perfect.
  - o This layer also contains the attribute for Kittle Number – so it identifies full watercourses from headwaters to mouth.
- Map **dnr_rivers_and_streams** strm_type to NHD FType.
- QC connectivity and directionality
- Assume we are using the **dnr_rivers_and_streams** as the new 1-d streams linework
  - o Look for geometric differences between **dnr_rivers_and_streams** and current **NHDFlowlines**.
  - o Where differences are small, use DNR.
  - o Where differences are larger, compare both data sets with ancillary data sources (e.g., imagery, liDAR, AW) and use the better delineation, adding it to the input base if it is not already there, and copying the amended linework to an “exceptions” file. If neither delineation is correct, delineate a new line for the input, and post that to the “exceptions” file.
  - o With the chosen “Waterbody” layer turned on, identify headwaters lakes, extend 1-d streams into those lakes. Add a node at the junction of NHDFlowline and the NHD Waterbody on both the stream and the waterbody feature dataset. These additional stream flowlines are copied to the “exceptions” dataset because DNR data will not have them.
  - o NHDFlowline “artificial paths” that flow through Waterbodies cannot cut across islands and may have to be edited. This edit would have to go to “exceptions”.

NHDArea (2-d stream feature in NHD):

- o Use DNR Hydrography Open Water – codes for “riverine” and “inundation area” as the foundation for the new NHDArea input. DNR OW riverine features are a combination of data from a 100K base and new edited features (especially some major river and Mississippi Pool features).
- o ***Appendix 4*** compares DNR and NHD feature types that map to “NHDArea”
- o Recognize that existing **NHDArea** features are 24K-based and have had significant editing done on them and may have improved feature delineations. These improved features would have to go into the “exceptions” file to update DNR OW.

NHDWaterbody (2-d lake or wetland feature in NHD):

- Use **DNR Hydrography Open Water** as the input dataset to re-create **NHDWaterbody**.
  - o All features would be used to map to **NHDWaterbody**, except the “island or land” features (which do not belong in the NHD water features at all), and “Riverine Polygons” and “Inundation Areas”, which map to the **NHDArea** feature class.
  - o Mapping of feature types between **DNR Hydrography Open Water and NHDWaterbody** are outlined in the table ***Appendix 4*.**
  - o Where the **DNR Hydrography Open Water** WB_Type is “wetland”, that type should be mapped to NHDWaterbody feature type “Swamp/Marsh.”
- Where current **NHDWaterbody** has an improved delineation for a feature, or has a feature that **DNR Hydrography Open Water** does not have, use that feature. Add that feature to the “exceptions” file (along with noting the DNR feature that it replaces) for DNR to fix in their database.
- Look at the MPCA’s “Custom Shapes” lake and wetland polygons for features that need to be added to both databases. MPCA creates “Custom Shapes” to delineate a feature that is not in the NHD but for which they have sampling data. These lakes need to be added into the NHD, and DNR would be interested in having them in the OW file also. MPCA’s source delineations for “Custom Shapes” are generally open water, and MPCA usually consults the DNR datasets to find a delineated feature first.
- If there are waterbody features that do not make sense, delete them (and make a note in the “exceptions” file –so that they are deleted everywhere.)
- Headwaters lakes need to have a node created where stream flows out, so that stream can be extended into the lake.
- DNR needs the island feature polygons so we need to figure out how to accommodate them.
- *Note:* while we are not using DNR PW data for NHD production, DNR has a business need for the Open Water lake polygon to be covered by (coincident with or smaller than) the corresponding PW polygon. So, even if this process never edits the PW, we need the PW as a background layer to make sure that a waterbody edit does not violate this rule. PW is normally larger because it can contain fringe wetlands. If editors believe that a PW polygon representation is incorrect and would like to extend an “open water” polygon outside of a PW Basin polygon, which would have to be resolved with DNR staff in charge of the PW layer***.***

Updating the DNR Hydrography Database

Features from the "exceptions" files must be incorporated by DNR into the DNR Hydrography Database. Then when a new extract is pulled from DNR Hydrography for conflation, all of the preferred features will be in the input data set, and the DNR data and the conflated NHD will be coincident.

Processing Prior to Conflation

Once the three input layers are geometrically appropriate and are in NHD format, the new Flowline layer will be intersected against the new 2-D Area and Waterbodies layers to create the final feature type changes. In order for this information (breaks at feature types) to remain coincident with DNR, then the three layers will have to remain geometrically coincident. In addition, the existing NHD input NHDLine feature dataset must be compared to the new DNR data and edited wherever it is misaligned.

NHD Conflation Tools Testing

MnGeo and MPCA received training on the use of the NHD Conflation Toolset in 2009. DNR did not take the full toolset training, but was involved to the point of discussing data inputs and identifying differences between the data sets and data requirements for each data set. MnGeo and MPCA did some further testing of the tools, with MnGeo providing updates to the USGS NHD dataset using the Conflation Toolset current at the time and data inputs from the DNR. This resulted in updates to several HUC-12's in 04010101 (spring, 2010), and an understanding of how the input data needed to be prepared in order to create NHD data from DNR data. The tool has been updated since then but the basic process is believed to be the same. MnGeo's experience with the NHD Conflation Tools is covered in *Chapter 5*.

Unresolved Issues

This chapter summarizes the data inputs for a new synchronization between the DNR and NHD hydrography layers. After investigating different input layers and editing issues, solutions were found for most problems. However, there are a few remaining unresolved issues which need to be highlighted. These need to be resolved in order to develop a successful conflation process between the DNR and NHD data sets for the future. These unresolved issues include:

- Island polygons within the DNR lakes data set
- Border Issues - Artificial path stream flowlines along state borders
- Extending stream flowlines into headwaters lakes (NHD Data Model Issue)
- Two DNR lake polygons issue - PW Basin cannot be built as event on OW polygon

Island Polygons within the Lakes Dataset

The DNR Hydrography Open Water feature class contains a feature type of "Island or Land", which is considered to be a necessary feature. The NHDWaterbody feature class does not contain any feature type that could reasonably hold the island feature. DNR considers this feature to be very important to maintain because it is useful to calculate land areas that are contained within water areas.

For the purpose of deriving a new NHDWaterbody feature class from the DNR Open Water feature class, the "Island or Land" feature type could just be disregarded as a source for the NHDWaterbody polygons. However, for DNR to be able to use the NHD as a base dataset, and using the NHDWaterbody as the feature class that was derived from their original Open Water layer, then the "Island" feature type would have to be maintained. This would also be an issue if we used the PW Basins layer as the NHDWaterbody input (i.e., PW Basins also contains – and requires - the "Island" feature). Also, stream flowline artificial paths in lakes need to avoid land areas in the NHD.

MnGeo has consulted with the NHD Team at USGS about the issue of adding an "Island" feature type to the NHDWaterbody feature dataset. The USGS response is that this issue comes up periodically, and that USGS is unwilling to add an island feature because that feature represents land and not water. Minnesota will have to investigate workarounds, such as creating and managing an island feature dataset that has a topological relationship with the Open Water-derived NHDWaterbody. This is a significant roadblock to achieving a single, statewide spatial hydrography dataset that meets all business needs. Proposed workarounds look cumbersome.

Border Issues - Artificial Path Stream Flowlines along State Borders

A state dataset (such as DNR) can maintain its flowlines all within a state border GIS dataset. A national data set (such as NHD) will maintain a single river main stem flowline through a 2-d feature in a HUC-8, where that 2-d feature defines a state border (e.g., main 1-d path of the Mississippi River below Hastings, MN). Where the state border is defined by a 2-d river, the "true" border is a theoretical line (generally, the center of the main flow path at the time of statehood), that is approximated on most maps and GIS datasets. The artificial path flowline may be arbitrary or, at best, represent a main navigation channel, which may cross the state border. For compilation purposes, both states want to have the artificial path flowline inside state borders, when these features meander across borders, and it is impossible for both states to physically "claim" the flowline unless the flowline is coincident with the state border feature. These 1-d stream features capture river mileage that both states need to manage. This is a theoretical problem with practical consequences.

- For mapping: For mapping purposes, even if the 1-d stream flowlines were clipped to the state border, the 1-d stream flowlines would probably be overlain with the 2-d stream areas for mapping purposes, so that the map would not display "breaks" in the stream. A question remains whether DNR would retain a "clipped to the border" version of an NHD-derived streams layer or not.
- For hydrologic modeling: Hydrologic modeling requires a single flowline to maintain the network, but you are generally dealing with the entire hydrologic unit at that point, and whether the flowline remains within the state or not is not critical.
- For tabulation of river mileage: River mileage calculations need the full 1-d stream mileage. Having stream segments "clipped out" by the state border is not tenable. Possible work-arounds that could become a documented and repeatable process:
    - Create a buffered state border dataset so that all major river 1-d features are within the "extended" state. Summarize 1-d stream mileage. Buffering probably added some small extents of non-state tributary streams. These could be edited out of the buffered "extended state" feature, and the total stream miles calculated again. The difference between the summarized extended stream miles with and without the non-state tributary streams is a mileage to be saved and used to subtract out of all future summarizations. All future

summarizations of stream mileage should use the same buffered state border so that state summary information and the amount to be subtracted remains consistently-generated.

  - Remove border river 1-d streams from the state area to be summarized; summarize mileage information for those border rivers separately, then add the two areas together. Border rivers can be "selected out" for separate processing either by DNR Kittle Number (DNR Streams) or by GNIS ID or Reach Code (NHD Flowlines – for entire named watercourse or selected reaches, respectively.)

- For creating derived layers for main flow path (DNR Fisheries and Waters): As an integral part of this research, DNR proposed using the NHDFlowline as the 1-d streams feature, then creating the derived DNR streams feature classes (such as trout streams, Public Waters Watercourses) as NHD events. Having those layers corrupted by clipping at the state border is not workable.

Extending Stream Flowlines into Headwaters Lakes

The NHD Data Model requires that, for the purpose of maintaining connectivity, a stream connected to a headwater lake must be extended into the lake. DNR generally begins the stream at the headwater lake outflow. To make the 1-d streams datasets consistent, they would both need this feature. In the case of DNR, these stream segments could be coded so that they could be removed from calculations or derived products. However, if the delineations came from NHD (where it does not have a code that distinguishes it from other "artificial path" features) it would be more problematic to identify (e.g., an artificial path through a waterbody feature that flows out of the feature but does not flow in). It might be possible to identify all artificial paths, then reselect those whose from-node and to-node intersect with a polygon boundary then drop the rest, or use something like the DNR "fetch" tool to create the upstream portion. It looks as though there is an acceptable work-around for this problem, but this needs to be tested.

Two DNR Lake Polygons issue: PW Basin cannot be built as event on OW polygon

Because it is the smaller polygon, it is not possible to create a "Public Waters" event polygon on an NHDWaterbody polygon that was created from Open Water. This requires DNR to maintain a Public Waters basins feature class outside of NHD. This is a significant roadblock to achieving a single, statewide spatial hydrography dataset that meets all business needs.

Adding Feature Types (changes to model)

Occasionally hydrography data developers determine that there is a need for additional feature type definitions in order to adequately describe an area's hydrography. (An example in past NHD history is the addition of a stream feature type of "ephemeral", to go along with "intermittent" and "perennial".) When a member of the NHD user community requests a change in the NHD Model to accommodate a new feature type, the USGS NHD Team will investigate and seek input from the NHD User Community through its NHD Advisory Team and other avenues. The NHD Team always has to weigh the advantage (to some users) of the additional feature type, against the disadvantage of having to change the NHD model and make the data more complex. The NHD Team will suggest other options or workarounds (such as storing the information as an event). If there is enough community support for adding a new feature type (or other change in the model), it will happen.

If DNR decides that they need a model change within its own DNR Hydrography Dataset, including additional feature types, there is a discussion within the DNR Water Resources Team. It is a much simpler process to add a new feature type DNR currently does not have to consult non-DNR users.

Two examples that may need discussion in the future are:

- the addition of a feature type for “inferred channels”
- the addition of a feature type for “drain tile” in agricultural areas.

The first is already under discussion by the NHD user community. The second would be beneficial to Minnesota since so much new or replacement drain tile has been laid in recent years. Additionally, county drainage records commonly include both ditch and drain tile systems: to adequately include drainage inventory information in either the DNR or NHD linework, a new stream feature type category would have to be added.

References

Appendix 4: DNR vs. NHD Water Feature Type Comparison
- a crosswalk table showing comparable DNR and NHD water feature types

Synchronization Resource Estimate

Full statewide synchronization of MN NHD and the DNR Hydrography Dataset

The resource estimate shows the main synchronization steps and low/high hour estimates for a single HUC-8 (Step 1) or HUC-10 (Step 2). Estimates are then multiplied by the number of Minnesota watershed units to process for each step.

Task	Staff Resource Costs	# units	Total hours (Low/High)
SECTION 1: Review/fix data (80 HUC-8 level)	**34-50 hrs per HUC-8**	**X 80**	**2720-4000 hrs**
Step 1: Perform Difference Evaluation between NHD and DNR datasets; Feature review to identify "best" features; Create "Exceptions" database	MnGeo Staff Processing & Review (6-12) DNR Staff Review (4) MPCA Staff Review (4)		
Step 2: Update DNR Hydro DB with "exceptions" features from Step 1 review	DNR Staff Processing (20-30)		
SECTION 2: Conflate data (532 HUC-10 level)	**8-12 hrs per HUC-10**	**X 532**	**4256-6384 hrs**
Step 3: Create input data set for NHD Conflation Process (from edited DNR data)	MnGeo Staff (2-4 hours)		
Step 4a: Conflate source data to current NHD Step 4b: Review conflation errors *Step 4c:* Verify that MN stream and waterbody totals match between NHD/DNR datasets	MnGeo Staff (4-6 hours)		
Step 5: Apply updated NHD dataset to national NHD database (Final QC and submission	MnGeo Staff (2)		
Contingency (Unexpected Problems)	**One-Time Costs**		**160-320 hrs**
	MnGeo Staff (120-240) DNR Staff (40-80)		
Totals	**MnGeo Staff (4856-7584)** **DNR Staff (1960-2800)** **MPCA Staff (320 hours)**		
	hours total		**7136-10704 hrs**

Table 4-1. *Estimated Costs for Full Statewide Synchronization*

NOTE: Staff hours may vary greatly by HUC-8 depending on the number and complexity of differences

NOTE: HUC-8 multiplier of 80 is based on the current WBD which reflects the US-Canada Data Harmonization project. Before this project remapped the HUC's in the Rainy River Basin there were 81 HUC-8's in Minnesota.

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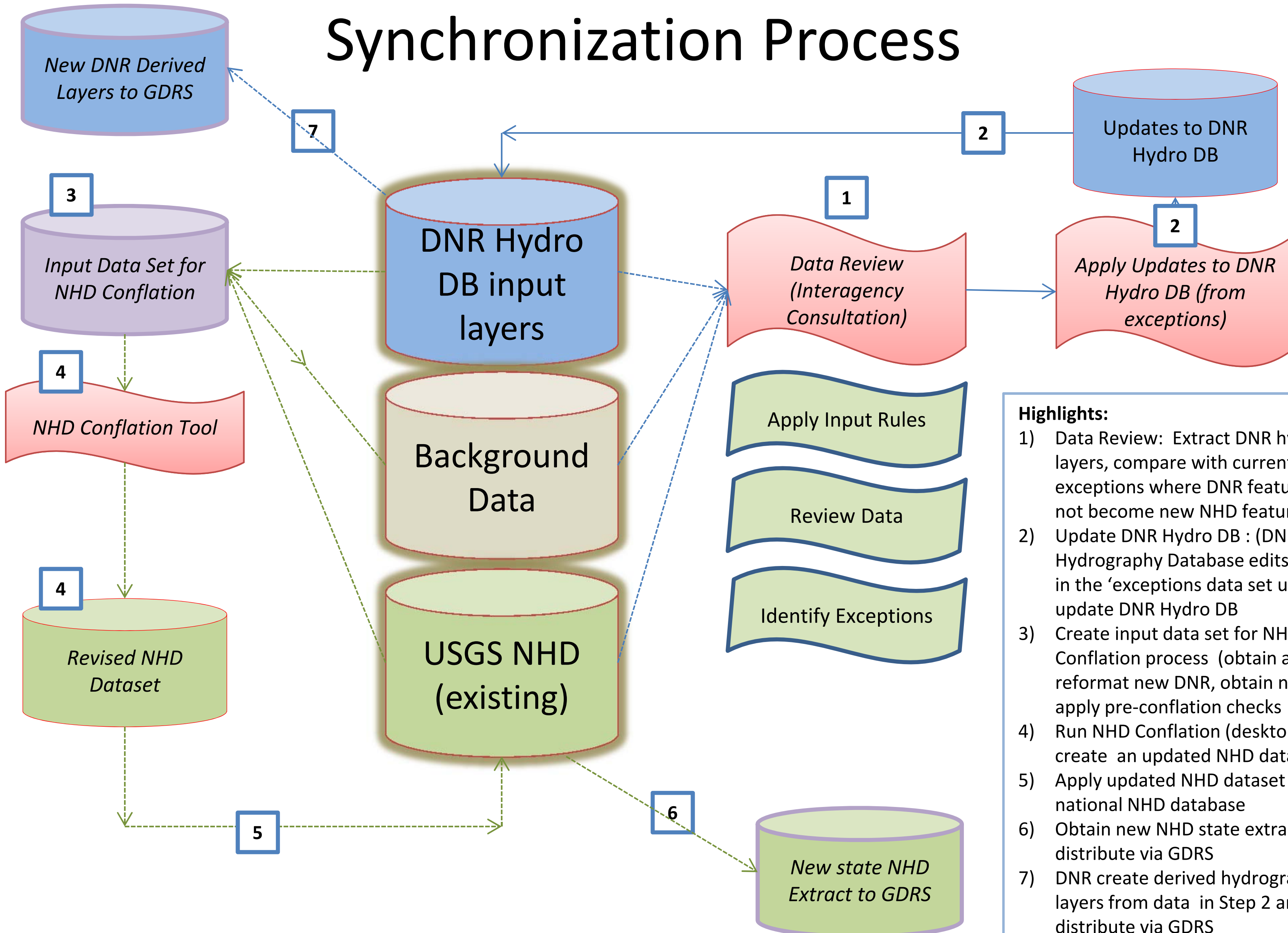
[i] Prior to the April 2012 Release of the NHD Update Tool v.4.0.0, previous versions of the desktop NHD editing tool were called "NHDGeoEdit". The new name was applied with the first release of the tool that was based on a replicate checkout from the NHD. The previous versions, the "NHDGeoEdit" tools, used a Status Table to track edits and an XML file to post updates back to the national NHD database.

DNR-NHD Hydrography Data Synchronization Process



Highlights:

1) Data Review: Extract DNR hydro layers, compare with current NHD, ID exceptions where DNR features do not become new NHD features.
2) Update DNR Hydro DB : (DNR Hydrography Database edits) features in the 'exceptions data set used to update DNR Hydro DB
3) Create input data set for NHD Conflation process (obtain and reformat new DNR, obtain new NHD); apply pre-conflation checks
4) Run NHD Conflation (desktop) tool to create an updated NHD dataset.
5) Apply updated NHD dataset to national NHD database
6) Obtain new NHD state extract and distribute via GDRS
7) DNR create derived hydrography layers from data in Step 2 and distribute via GDRS

Figure 4-1

Chapter 5 : Synchronization Pilot Test – Process and Results

Objective

This chapter outlines the steps required to move Minnesota spatial hydrography data, mainly from Minnesota Department of Natural Resources (MN DNR), to an NHD format that can be submitted to the USGS National Hydrography Dataset. The discussion is based on a pilot project that was done in 2009 using the NHD Conflation Tool to update the NHD based on improved DNR linework. A new release of the NHD Conflation is expected in 2014, which will change the processing routines somewhat. Chapter 4 describes how data inputs for conflation will be handled for any future work.

Results & Conclusions

- These steps are based on USGS Conflation tools available for ArcGIS 9.3. Tools to run on ArcGIS 10 are expected to be available later in 2014.
- Reviewing and setting up the input data is crucial to getting the best results from conflation.
- Conflation is not totally automatic. One needs to review the results to ensure that everything was transferred as expected and that nothing was lost from the original data in the process.
- Review of the new conflation tool will be necessary to understand any differences from the procedure described below.

Procedural Details & Analysis

Synchronization Process Using USGS Conflation Tools - 2009

In 2009, MnGeo performed a pilot test for conflation using USGS Conflation tools available for ArcGIS 9.3. This tool was based on older formats of the ESRI software including Arc/Info AMLs, Arc/Info coverages and Info tables. A new conflation tool is being developed in ArcObjects to be useable in the ArcGIS 10 platforms. Our assumption is that the new tool will follow the general requirements and steps of the original conflation tool.

Additionally, most of MnGeo's editing experience for general updates has been with the original NHD GeoEdit Tool, which allowed more control over adjusting tables to force changes or to "sidestep" the tool. The new NHD Editor tool has an easier and cleaner process but without the ability to sidestep the tool. Our conclusions are based on knowledge of the original tool used in the 2009 pilot test and may no longer be relevant in the new edit and conflation environments.

The procedure described in this document is based on the pilot test that was performed in 2009. It consisted of four HUC-10 areas in HUC-8 04010101 (i.e., Baptism-Brule – USGS Name; Lake Superior North – DNR name). For the pilot test, MN DNR provided both Public Waters (PW) Basins and Streams with Flow Directionality as input data.

The pilot test consisted of:

- Reviewing and setting up appropriate data inputs
- Using the conflation tool to match the MN DNR input data to existing NHD data and to transfer NHD Reach Code identifiers and GNIS names to input features
- Sending the finalized conflated data to the USGS NHD dataset

The process for the test conflation included:

1. A decision regarding the Watershed Boundary Dataset (WBD) extent to be conflated

   The WBD defines the aerial extent of the surface water drainage and are classified into hydrologic unit codes (HUC's). The HUC code indicates the location of a drainage area; the HUC level indicates its relative size. The NHD has been built upon the HUC-8 digit (level 4) areas, also known in Minnesota as the DNR major watersheds. While our general NHD updates have been performed on HUC-8's, the 2009 test conflation was performed on HUC-10's.

   The following figure shows the relative size of county, HUC-8 and HUC-10 boundaries in Minnesota. There are 80 HUC-8's and 532 HUC-10's that exist partially or completely within Minnesota.

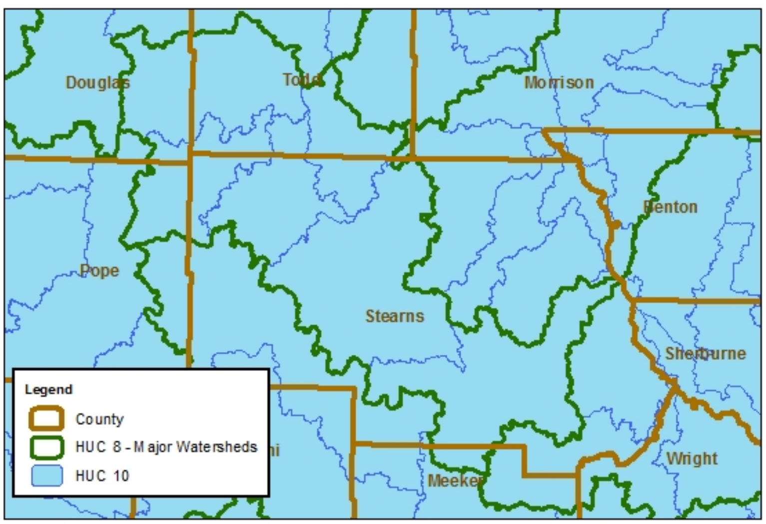


Figure 5-1. *Relative sizes of county, HUC-8 and HUC-10 boundaries in MN*

   Typically, the conflation is done at the HUC-8 extent. For areas that are more complex with a large number of differences between the datasets, a smaller subset may be more appropriate. Areas larger than the HUC-8 are discouraged since it is difficult to monitor and check all of the changes that result.

If areas smaller than a HUC-8 are used, the original conflation process had a separate tool to make sure that all of the relevant NHD tables were selected and populated properly. Also, the data needs to be reviewed to see if any streams or lakes are selected that touch or partially cross the HUC-10 boundary. These features may create a conflict, particularly for coding, if they overlap with other existing NHD features in the neighboring HUC-10's. For example, part of an NHD Flowline may be coded as an artificial path because it crosses a lake in the next HUC-10. However, the processing tools would see this as an error since the lake was not part of the selected dataset. In this example, this arc should either be excluded from the input dataset or the corresponding information should be added to the NHD Source data so that it is conflated properly.

2. Selection of the Data Inputs

   There are three layers required for input to the NHD during the conflation process: 1) a linear (1-D) representation of the stream/ditch network, 2) a polygon (2-D) representation of wide streams such as the Mississippi River, and 3) a polygon (2-D) representation of lakes/ponds/reservoirs. There are other point and line features in the NHD hydrography dataset that consist of features such as dams and gages from DLG source data. Since Minnesota NHD mainly originated from MN DNR data, these datasets are usually empty and would not be added as inputs. At the time of the pilot test, the conflation tool was not handling them. However, one will need to check the requirements for the new conflation tool (i.e., whether to leave them empty or to copy the data in NHD to the input NHD dataset.

   Prior to conflation, the NHD data layers need to be compared against the MN DNR layers using aerial photography to determine which dataset has the best features. The MN DNR and NHD datasets have been edited at different times for different purposes, so that portions of the data may be better in one dataset. In addition, the Minnesota Pollution Control Agency (MPCA) or other known editors in that region should be contacted to see if they have additional changes that are not yet in NHD. The rules established in Chapter 4 will be used to determine if certain layers have priority. If it is unclear which dataset has the best features for a given area, the data stewards from the different organizations will review the data to make a decision on how to proceed.

   From MnGeo's experience with the pilot project, it is recommended that when the input data is selected, the first step would be to add a field to each database and record the feature source as either "MN DNR" or "NHD" or "MPCA", etc. These may be edited or moved in the next steps to connect networks, but it will provide an indication of the initial feature source.

3. Review and Preliminary Edits of the Data Inputs

   All of the data for the three layers that make up the final NHD dataset need to be in the input layers prior to conflation. Any feature in the original NHD dataset that does not match a feature in the input dataset will be marked for deletion.

   It is possible that features from both layers will be used as inputs. For example, if the NHD flowlines have been improved to better match the imagery in part of the HUC and the MN DNR data has re-digitized stream features in another area, these features can be brought together to be used as the final input data.

Inputs and Edits for NHD Waterbody Layer

The original NHD waterbody data layer was mainly built using MN DNR 24K lakes that originated as open water polygons and fringe wetlands from the original National Wetland Inventory dataset. The original NWI for Minnesota was interpreted over the period 1991-1994, using source photography covering the period 1979-1988. This layer included many tiny lakes and ponds that, when compared to current aerial photography, do not appear to exist as permanent features or were in fields that are now drained. The current input data layer from the MN DNR does not include these small features. The rules in Chapter 4 indicate which ones will be retained in the final conflated NHD dataset. However, if any of these smaller pond features are included in MPCA assessments, they must be retained.

During the 2009 pilot test, multi-part polygons were found in the MN DNR waterbodies input data that caused errors in the NHD data model. However, the current MN DNR data has been corrected and this will no longer be a problem in future conflation.

Another issue was that GNIS names and IDs in lakes were not assigned to the multiple waterbody polygons in the NHD database and to single polygons in the input data layer, causing conflation to fail.

- Since Minnesota used MN DNR lakes that were based on open water polygons for the initial creation of 24K NHD, there were several situations where a "lake" consisted of multiple smaller polygons. Our updates to NHD during test conflation included new single lake polygons to replace multiple ones in the existing NHD. If these lakes had an associated GNIS name and ID, not all of the polygons in the 24K NHD were always assigned the GNIS name and ID.

- Our solution was to add the GNIS name to all associated polygons in NHD prior to conflation. It did not matter if the NHD attribute was changed, even though it did not exist in the USGS database that way. The NHD is only being used to transfer attributes to the conflated input dataset. Only the results of the conflation are sent to update the federal USGS NHD dataset.

Inputs and Edits for NHD 2D Area Layer

In the initial conflation test, the 2-D area features in NHD originated from the MN DNR 24K lakes layer. Some of the waterbody polygons were coded as riverine and were moved into the NHD area layer. Since the MN DNR layer originated from the NWI open water polygons, small riverine features can be found near to or at some distance away from streams. These features do not appear to have significant use or meaning and will not be included in the final conflation datasets.

For future conflation the DNR 2-d area inputs would again be used. But as discussed in Chapter 4, these would be amended with 2-D area data from the current NHDArea feature, and the best representations would be incorporated into the DNR input layer before the conflation process commenced. Then, additionally, the match between the 1-d stream features and the 2-d area polygons needs to be confirmed: the 2-d area features need to fully contain the input stream line features that flow through them.

Inputs and Edits for NHD Flowline Layer

Several types of review and edits are required for the NHD flowline input layer. First, the network and connectivity needs to be maintained. In our pilot test, the MN DNR streams were built as routes with the directionality extending from stream mouth (mile 0) to upstream headwater endpoint (i.e., in the opposite direction of stream flow). These routes needed to be flipped in order to provide the correct flow directionality for the NHD network. Additionally, the FlowDir field in the input template had to be calculated to "With Digitized". If linear features are used from both NHD and MN DNR, we will need to ensure that they snap to each other at nodes.

In the NHD data model, the flowlines are extended into headwater lakes to enable the network to flow into the lake. Since MN DNR does not include these small segments, they will need to be added for areas where the MN DNR streams are used instead of NHD flowlines. Nodes must be placed anywhere that a stream intersects a waterbody polygon. In some areas, this can include a large number of lakes and some of them can be small. It may be beneficial to develop a tool to look for these lakes as well as identify which ones the MN DNR would not want to include in their data.

Input flowlines need to be reviewed to make sure they stay within the input waterbody or 2D area, where appropriate. When different sources are used in conflation for these three layers, the flowlines may stray outside of the polygon boundaries. During the test conflation, some new flowlines crossed over islands. It is important to correct these errors because line segments outside of a water polygon may require new reach codes even though the line segments are very small.

Examples from our pilot project include:

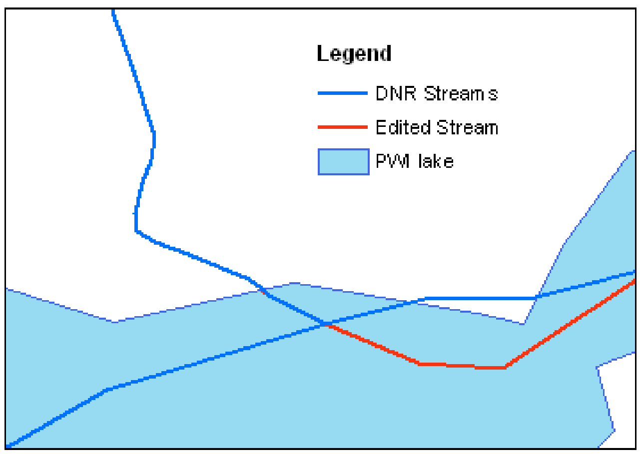


Figure 5-2. *DNR & edited stream within a PWI lake*

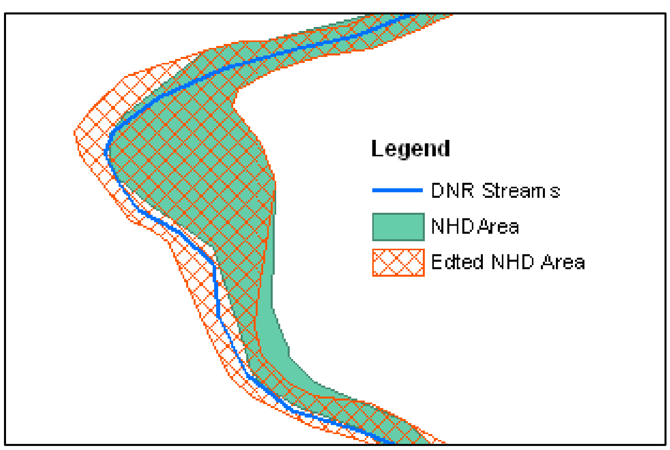


Figure 5-3. *DNR stream outside NHD 2-D Area*

As shown in the above examples, the flowline was edited to stay within the lake and the 2-D area was edited to include the stream. Current aerial photography will need to be reviewed to determine the correct solution.

Other checks that were done during the pilot project were using NHD tools to verify that all of the new flowlines occurring within a waterbody or 2-D area were classified as artificial paths and that no artificial paths occurred outside of these polygons.

Once the new flowline layer has been completed, one can create a network and check that the flow works properly. This was also the first step in the conflation tools, although some of the necessary edits to correct the problem appeared to be easier outside of the tool. The new conflation tool should be reviewed to determine if an initial network check should occur.

4. Transfer of the Data Inputs into a NHD Geodatabase format

To begin the conflation process, the new data needs to exist in an NHD Geodatabase format. At the time of our pilot test, we had NHD templates in Albers projection that could be used for the input data.

During the pilot test, only the NHD Flowline, NHD Waterbody and NHD 2-D area layers were required to be populated with the new data features. All of the other tables and layers were empty.

Using the crosswalk between NHD and MN DNR codes for flowline (***Appendix 4***), waterbody and 2D area types, the data was added to NHD and the proper NHD FTypes and FCodes were calculated. For the pilot test, the waterbodies and 2D areas were added to the template using the *Data Loader* option in ArcCatalog, since all of the input features were already from NHD. If multiple types are added during synchronization, using a similar method to the flowlines may be more appropriate. Input flowlines were added in an edit session in ArcMap. Individual types were selected from the edited data input layers, copied and pasted into the appropriate NHD layer, and the FTypes and FCodes were calculated while the features were still selected. For example, all "perennial" streams were selected from the MN DNR input layer, copied and pasted to the template, and calculated to the NHD perennial codes.

5. Run the conflation tool

The conflation process recommended performing topology and gapped GNIS checks (named watercourses which are missing GNIS names along a portion of their extent) for the data downloaded from NHD. A gapped GNIS is where the GNIS fields for some of the line segments along a GNIS named flowline were missing values. The data for Minnesota typically did not have these problems so it was not done.

The conflation tool from the pilot test used a form to move through the processing steps (below):

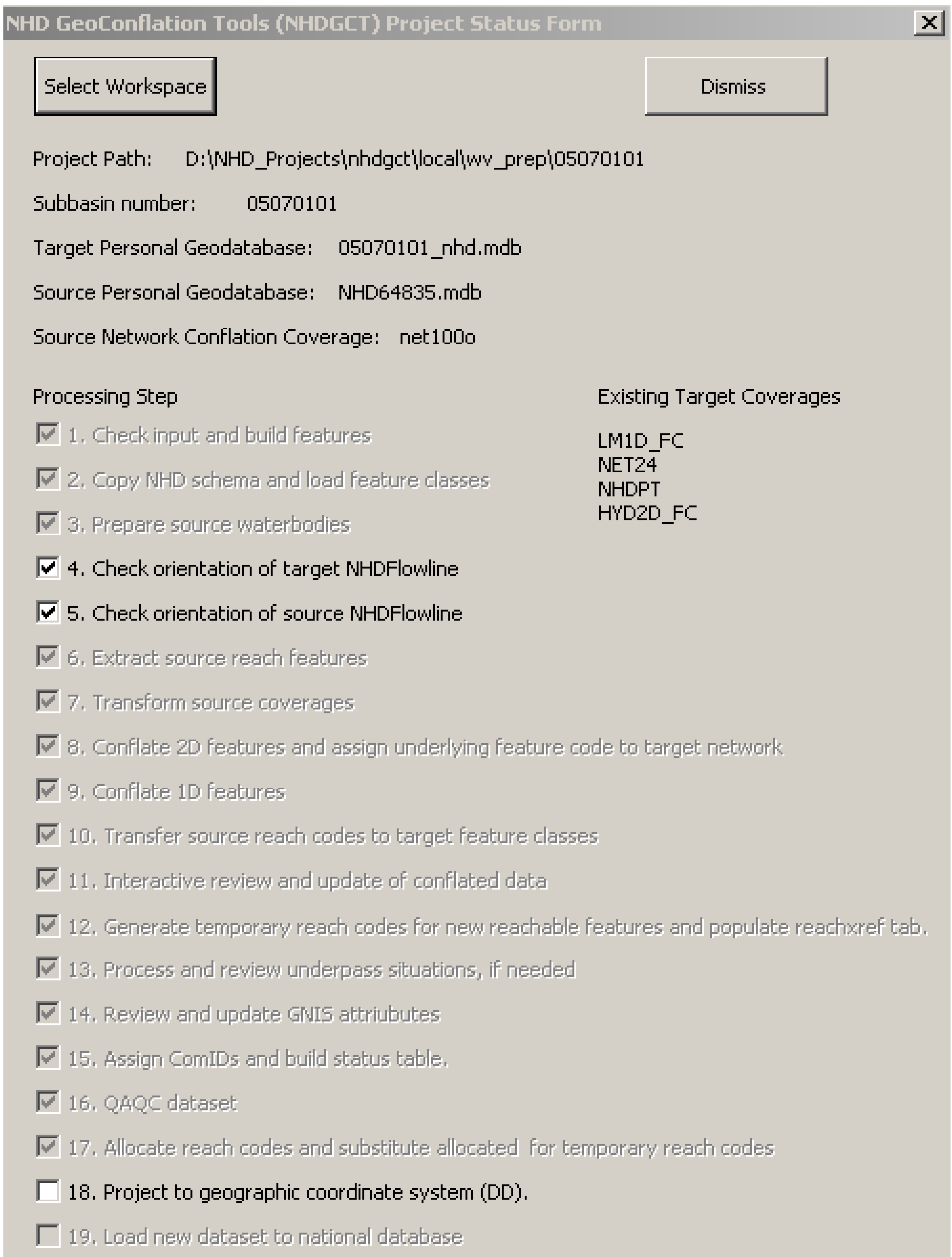


Figure 5-4. *NHD GeoConflation Tools dialog*

At step 11, one would look through a queue for places where the transfer of NHD reach codes was not automatic to the new input data and make decisions on how they should be handled. These decisions were handled through an interface as shown below for waterbodies. A similar one existed for flowlines.

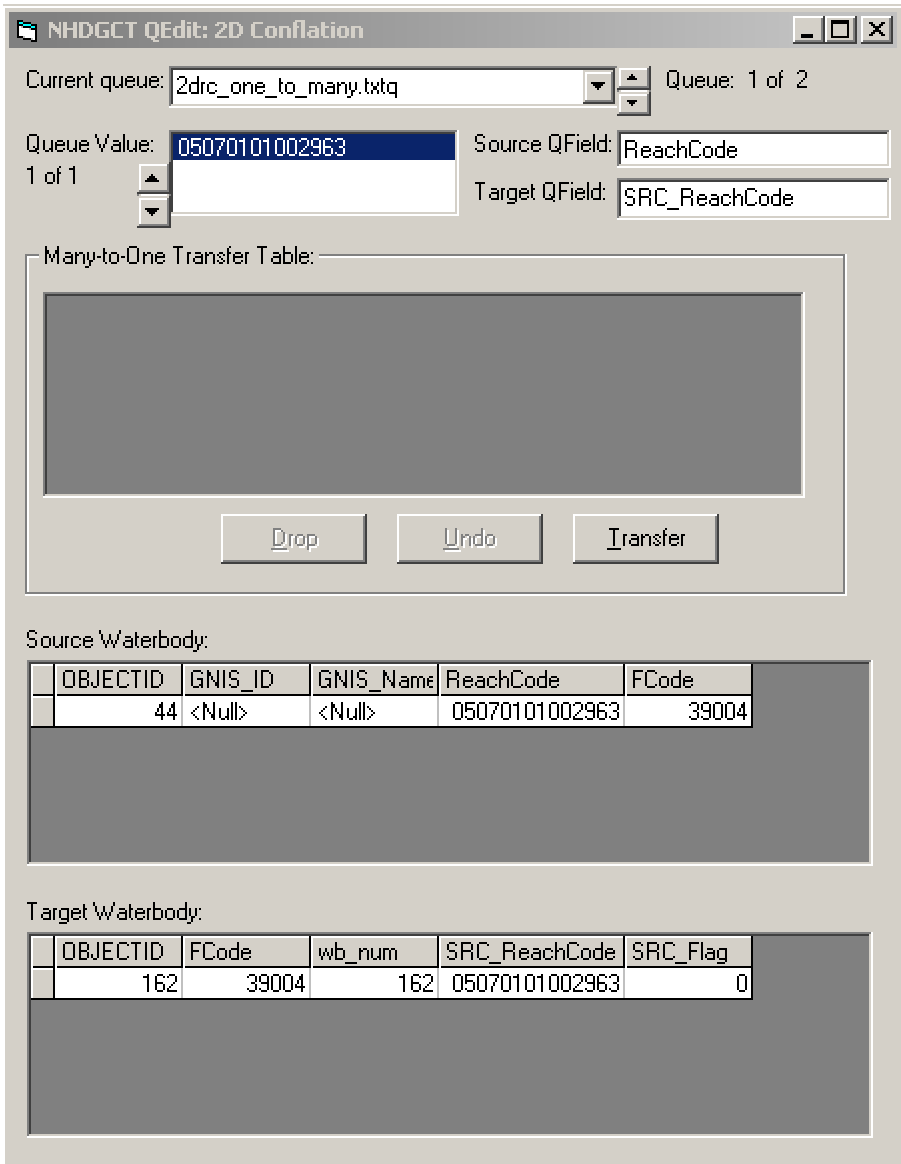


Figure 5-5. *Waterbody interactive conflation dialog*

For waterbodies, the drop down menu for queues included:

- reach codes associated with more than one waterbody
- source reach codes not transferred to any target waterbody

A picture would be displayed to show the problem:

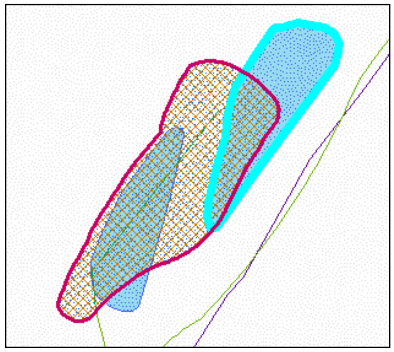


Figure 1-6. *Target polygon (red outline with hatching) & two NHD source (blue) polygons*

For flowlines, the drop down menu for queues would include issues such as:

- source reach codes not transferred to any target flowline
- source reach codes that are transferred to more than one target feature and these features are not completely connected (i.e., gap exists)
- source reach codes with features that are not within 150 map units of any target feature at 4 of 4 reference points along the source reach
- source reaches match at one to three of four reference points
- target NHDFlowline features have more than one source reach code transferred to it

Synchronization using the revised NHD Conflation Tools – 2014 and beyond

Overview of 2014 Version of USGS Conflation Tool

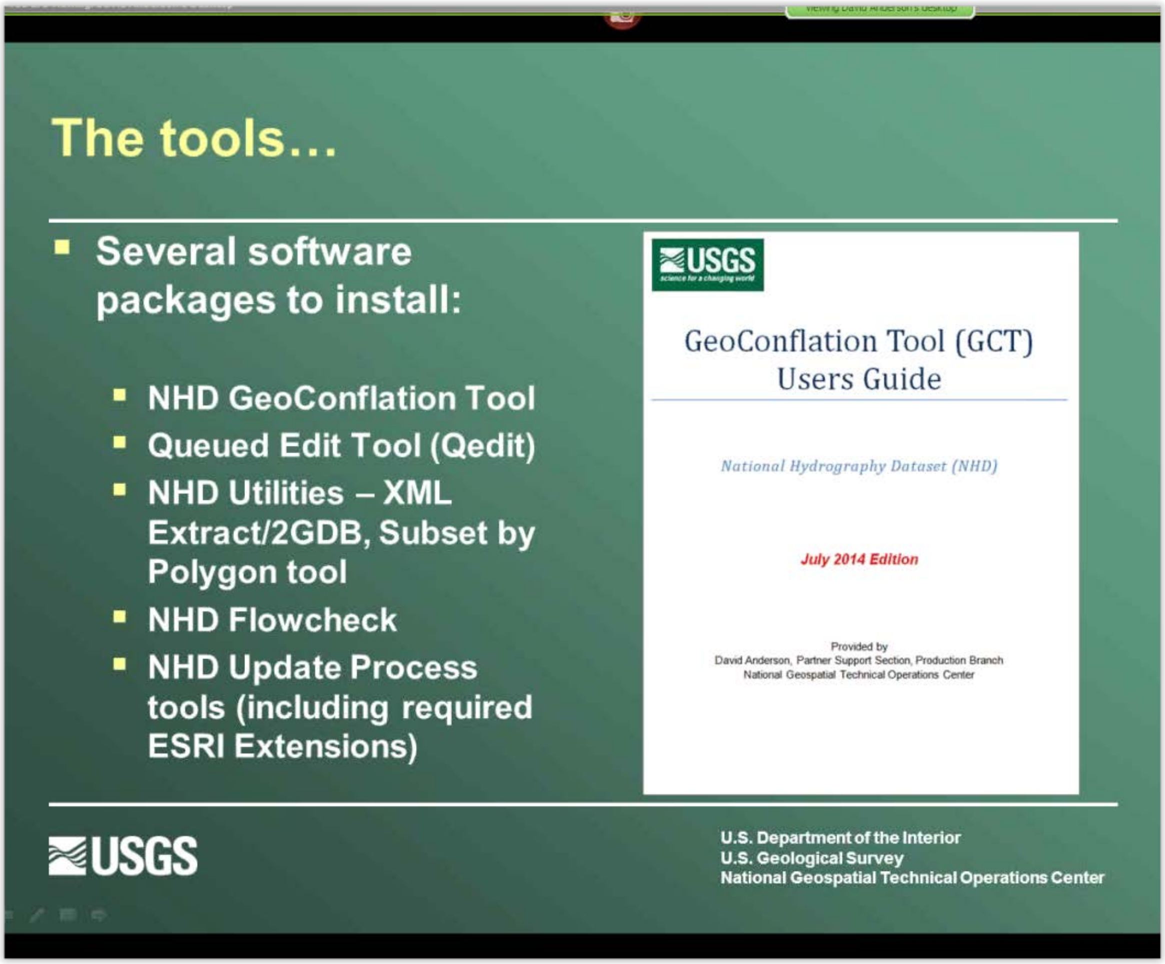


Figure 5-7. *Overview of 2014 Conflation Tool Presentation*

USGS presented an overview of their new ***2014 NHD Conflation Tool*** on June 25, 2014. (The tool has not yet been released). The process was very similar to what was used in 2009. Questions that were raised earlier in this chapter about whether the new process and tool has changed any of the steps were addressed. Highlights from this presentation are as follows.

- The most time consuming part of the process is to get the input data ready. This includes making sure all of the flowlines, waterbodies and 2D areas are included and complete. Emphasis was placed on checking the flowline paths through waterbodies and 2D areas.

- The new tool begins by opening a job through the normal NHD Update process. A copy of the data from the job is made for the conflation process.

- An NHD template in an Albers projection is provided to run conflation. This is necessary in order to be able to calculate distance and area values.
- The only attributes that need to be calculated in the input data are Flow Direction, FType and FCode. The other attributes will be transferred from the original NHD Data.

- Anything not included in the input data will be marked as a delete. This includes the NHD Point and Line features. Since Minnesota will not be providing new data as part of the conflation process, there are two options to prevent the existing points and lines from being deleted as part of the conflation process. One can delete the points and lines from the NHD data features used during conflation so that one will be comparing an empty data set to an empty data set and nothing will be marked for deletion. Or one can copy the NHD point and line layers to the input data and the match will be perfect and nothing will be marked for deletion. USGS did recommend reviewing them, however, against the new input data to make sure that the dams and other features still line up with the flowlines, water bodies or 2D areas. It will be important when working with HUC's that cross state boundaries, to **not** delete features in the bordering states. That will mean copying any features from NHD not in Minnesota into the input dataset.

- The optimum size for the conflation tools is about 40,000 records which is equivalent to a HUC-10 or HUC-12. There will be a Subset by Polygon tool, similar to the 2009 tool to properly select the NHD features and tables. There may be features that cross these boundaries that will be included because they are a continuation of the same reach code or identifier. One should **not** use clip or edit tools to make the HUC end at the boundary. What will happen during conflation is the clipped feature will replace the larger one in the USGS database.

- Once the input data has been prepared and placed into an NHD format, it is ready for the conflation tool. At this point it is a process and not an editing environment. One will no longer be able to make edits to the data but only make choices on how features match. The steps in the new tool have been streamlined and the 1D and 2D queues to look at the situations where events do not automatically match has been incorporated into a single interface. USGS said that typically 80-95% of the data transfers with an automatic match and does not go through the queues.

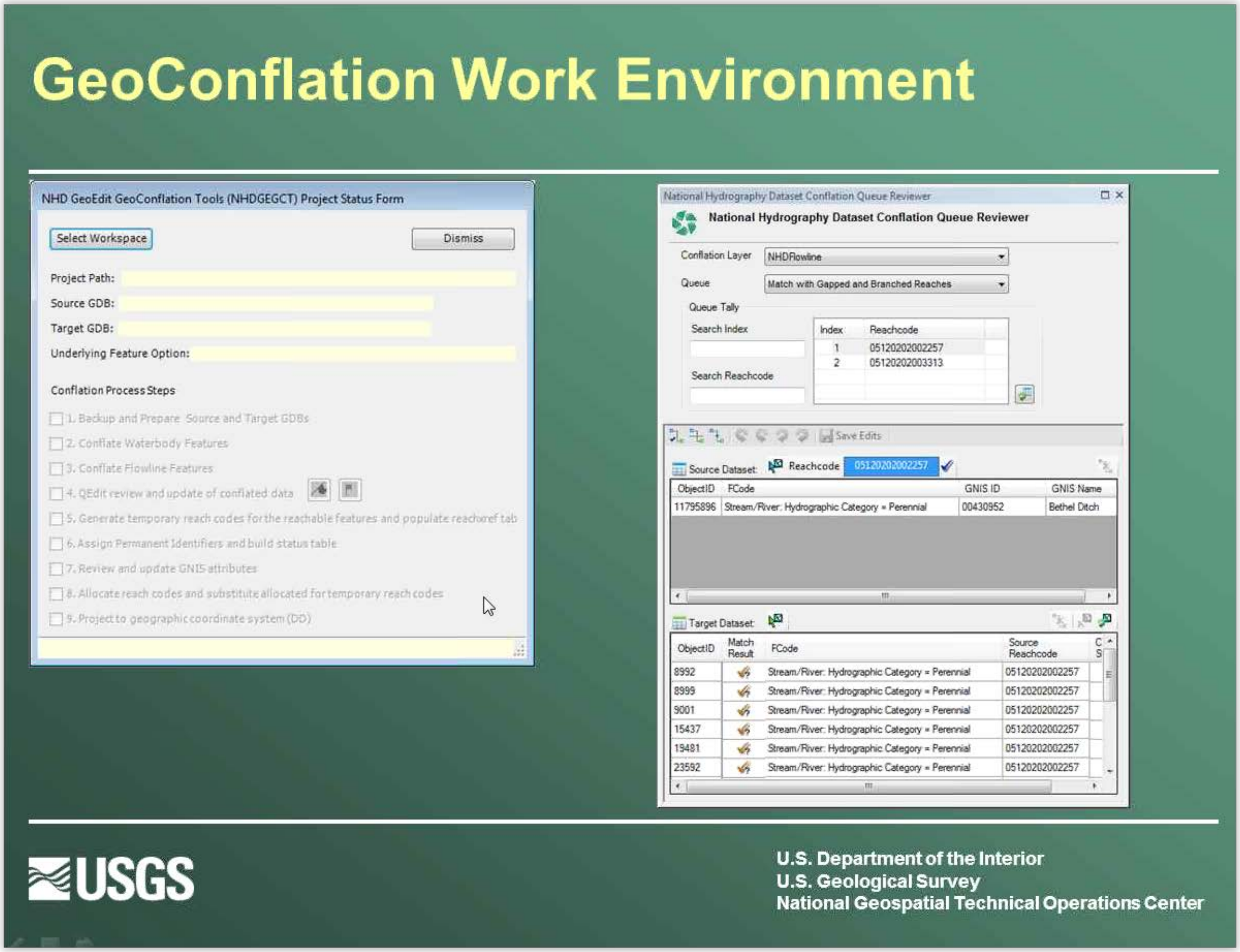


Figure 5-8. *2014 NHD GeoConflation Tools dialog*

- To transfer the new data to the USGS NHD database, the conflation tool prepares an XML Extract, XML2GDB and RCL files that are similar to the 2009 conflation tool and the old NHD edit process. These files are based on a status table that keeps tracks of all of the additions and deletions in the data set. These files are used to move the changes into the USGS job that was opened at the beginning of the process.

- To complete the job, the final Quality Control checks from the USGS NHD Update tool have to be performed and any major problems have to be addressed. It will be important to look at these is relation to how they may be different from the final MN DNR data set used as input. Are they minor network connections that were impacted when data was projected to Albers? If there are major differences from the MN DNR data, it may be better not to submit the job but to make changes to the original DNR data and redo the conflation steps.

Summary of Expected Future Conflation Process Based on USGS Conflation Tool and Chapter 4 Synchronization Rules

1. Select Area to be Conflated
    - Work will be done at the HUC-8 level (Chapter 4)

2. Select Data Inputs
    - MN DNR layers (dnr_rivers_and_streams for NHDFlowlines, DNR Hydrography Open Water for NHDWaterbody and NHDArea) (Chapter 4)

3. Review and Preliminary Edits of Input Data
    - Comparison to other data layers and aerial photography to determine necessary edits
    - When necessary, review any conflicts with partners
    - Finalize edits into MN DNR database, using MN DNR and NHD rules (Chapter 4)

4. Transfer of the Data Inputs into a NHD Geodatabase format
    - Copy final edited MN DNR data layers into a template of NHD data layers and tables
    - Calculate NHD FTypes based on crosswalk of NHD & DNR data types (USGS Conflation Tool)

5. Run the Conflation Tool (Conflation Processing will be by individual HUC-10's within a HUC-8)
    - Performs necessary checks on input data
    - Transfers the NHD attribute codes to the Input data
    - For similar flowlines and waterbodies automatic transfer
    - Steps through queues for flowlines and waterbodies where decision needs to be made (USGS Conflation Tool)

6. Transfer of the Final Conflated Data to USGS and MN DNR.
    - Send final conflated NHD data to USGS. (USGS Conflation Tool)
    - Final data edits were done in MN DNR database so no transfer necessary (Chapter 4)

References

Appendix 4: DNR vs. NHD Water Feature Type Comparison
– a crosswalk table for DNR waterbody class (WB_CLASS) vs. NHD Waterbody Type (Fcode, FType)

USGS Conflation Tool Documentation, 2009 (2014 when available)

Chapter 6: Maintenance Options

Objective

This chapter describes three possible model options for long-term maintenance of the state geospatial hydrography datasets. Options 1 and 2 were chosen for further pilot testing (see *Chapter 7*). Note that the final recommendation may include variations of any of the options described in this chapter.

Results & Conclusions

- Any effective model for the long-term maintenance of a statewide geospatial hydrography dataset will include technical strategies to address the following essential components:
    - Multiple Editor Environment
    - DNR Event Referencing
    - Pre-notification of Intended Edits
    - Review, Conflict Detection and Approval of Proposed Edits
    - Updates to Approved Edits into the MN State NHD Dataset
    - Updates to the USGS Federal NHD Dataset
- A strong Data Governance plan which includes effective interagency coordination, communication and stewardship will help to ensure the long-term sustainability of a multi-editor, statewide dataset.
- Three Maintenance Model Options were proposed to address long-term data maintenance needs.
    - Each model differs in the technical strategies it uses to address the essential components.
    - Each model has specific considerations, pros, and cons, while all models share some common considerations.
    - Many variations on the three models are possible.
        - The final recommendation may include a combination of strategies from each of the tested model options.

Essential Model Components

To be an effective solution for long-term maintenance of the state geospatial hydrography data, any adopted maintenance model must include the following **essential components:**

1) Multiple Editor Environment

At least three state agencies (i.e., MnGeo, MPCA and USFS) have expressed interest in being able to edit and update NHD geospatial features to address their business needs and to improve the state hydrography dataset as a whole. A fourth agency (i.e., DNR) maintains its own enterprise geospatial hydrography dataset but is interested in synchronizing it with NHD if feasible. A multiple editor environment allows authorized editors to access the base state NHD dataset and make proposed edits for approval by other partners.

In addition, there must be a mechanism for non-partner (i.e., external) editors to submit improved features for incorporation into NHD. Many resource professionals across Minnesota have improved water feature delineations to meet their own business needs and we need to capitalize on these efforts. Local improvements to a centralized geospatial hydrography dataset (like NHD) will allow users to rely on it for their business needs rather than having to maintain individual modified datasets.

- ❖ SDE versioned databases and shared web applications are two potential solutions for a multiple editor environment.

2) DNR Event Referencing

DNR has numerous "derived product" data layers representing different groupings of geospatial hydrography features. DNR currently maintains much of this data as events upon core DNR Hydrography streams and open water feature classes. To fully meet DNR business needs, any viable maintenance option must result in derived GIS products that match those currently being produced. Furthermore, DNR wants to retain control over the storage and maintenance of its statutorily-mandated data.

- ❖ Possible DNR event-referencing strategies include referencing derived data layers directly to NHD or to core layers generated from NHD.

3) Pre-notification of Intended Edits

In order to prevent editing conflicts and duplication of efforts, a *pre-notification* strategy must be established so that editors can notify partners of intended editing work. Other partners can then avoid editing in these areas and/or propose additional edits that could be made simultaneously.

- ❖ Pre-notification could be accomplished by a number of strategies, for example: 1) single email notification with print-screen of editing areas; 2) distributed ArcMap bookmarks of proposed editing areas; or 3) a shared web application such as ArcGIS Online (AGOL) with "mark-up" capabilities allowing partners to delineate and comment on proposed editing areas.

4) **Review, Conflict Detection and Approval of Proposed Edits**

An essential technical component of any maintenance option is the ability of partners to review, resolve and approve edits proposed by other partners. Each partner must signify approval of proposed edits so that core feature classes continue to meet agency business needs and so that edits made by one partner are not “undone” or in conflict with edits made by another.

- **Review** strategies range from simple to complex, including strategies such as: 1) using a WebEx or Lync session to review and approve edits by a group of partners; 2) distributing a shapefile of proposed edits to a central location or directly to partners; 3) viewing proposed edits reconciled with (but not posted to) a default version of NHD in SDE; 4) uploading proposed edits to a “provisional edits” review area within a shared web application that has Comment and Edit capabilities, such as an ArcGIS Online (AGOL) web application.

- **Conflict Detection** could be accomplished by a simple visual review of proposed features in comparison with current base layers or by use of standard ArcMap tools (e.g., SDE Reconcile and Conflict Detection, Data Comparison tool, topology errors, etc.) to detect differences among features.

- **Approval** can be signified by entering the partner name, date and comments into an “edit tracking” table or by posting notes into a shared web application. The use of customized web services may allow partners to upload features into a “provisional edits” geodatabase for long-term storage, providing a historical archive of past proposed and approved features.

5) **Updates to the MN State NHD Dataset** (for the GDRS)
After features have been approved by all partners, they must be incorporated into the state NHD dataset that resides on the GDRS. This makes new features available to users at the partner state agencies as well as across the state via the GDRS and/or the Minnesota Geospatial Commons web portal.

- Incorporation of approved features into the state NHD dataset can be accomplished by: 1) reconciling and posting in SDE from a partner “EDIT” version to the state “DEFAULT” NHD version; 2) direct updating of the state MN NHD dataset (on the GDRS) with the approved edits; or 3) directly copying the updated federal NHD dataset (see *Component #6*, below) to the GDRS to replace the current MN NHD dataset.

6) Updates to the USGS Federal NHD Dataset
After features have been approved by all partners, they must be incorporated into the USGS federal NHD dataset by an authorized **State NHD Administrative Steward** who coordinates two-way update activities between the state and federal NHD datasets.

- The steward may be: 1) a single, authorized agency steward that coordinates all two-way updates, or 2) a group of sub-stewards that are trained and authorized to make one-way updates directly to the federal NHD dataset. In the second case, a single “primary” steward serves as the official state NHD contact and coordinates one-way updates from the federal NHD back to the state NHD.

In addition to the above technical components, a strong **Data Governance** [i] plan will help to ensure the long-term sustainability of a multi-editor, statewide dataset. A successful governance plan will include effective strategies for interagency coordination and communication (*Appendix 7a*). Dedicated NHD "Stewardship" (a concept that refers to formal co-management of the NHD dataset by USGS and authorized state "stewards") is also essential (*Appendix 7b*).

Procedural Details & Analysis

Each of the three proposed Maintenance Options incorporate specific technical strategies to address the components above. The following pages describe each model option in detail. See ***Table 6.1*** (at the end of this chapter) for a summary comparison of the strategies tested within each model option. Test results and conclusions can be found in *Chapter 7*.

Option #1: Direct editing to a central SDE MN hydrography dataset (*Figure 6-1*)

Under Option #1, state agency partners (MnGeo, MPCA, USFS and DNR) edit directly to agency-specific "edit-versions" of NHD within a centralized SDE database maintained at the state level. SDE versioning, topology rules and topological-editing tools are used to achieve feature synchronization and detect conflicts among edits. A customized *pre-notification-review-conflict resolution-approval* process is used to achieve agreement of proposed edits among all partners. A primary State NHD Administrative Steward reconciles approved edits into the state NHD dataset (default version) and uses established NHD processes to update the USGS federal NHD dataset.

Highlights of this option are:

1) Multiple Editor Environment

Partners make edits directly to agency-specific edit-versions of NHD within a centralized SDE dataset.

- All agencies use the MN default version of the NHD (in SDE) as the reference dataset; the agency-specific "edit versions" are *temporary versions* used for editing and reconciliation only.
- **Topology rules** are established to govern spatial relationships between features of different feature classes and to identify errors that violate these relationships.
- **Topological editing** is used so that if coincident or adjacent features within a Feature Dataset are modified, the other features are also updated automatically.
- The **SDE versioning-reconciliation** process identifies conflicts among similar features that have been edited by more than one partner.

2) *DNR Event Referencing*

Two core DNR feature classes (for streams and open water only) are referenced as events to NHD.

- DNR uses *Linear Referencing* tools or NHD HEM tools to reference core data as events to NHD
- Referenced events are exported to replicate the two current DNR core layers for the GDRS (i.e., *Stream Routes with Kittle Numbers and Mile Measures* and *Open Water* polygons).
- Other DNR hydrography data is referenced to these core layers and exported as derived products to the GDRS using current (automated) business practices.

3) *Pre-notification of Intended Edits*
Authorized partner editors notify other partners of areas where they intend to make edits.

- Pre-notification is via email, distribution of a shapefile, or by sharing ArcMap bookmarks.

4) *Review, Conflict Detection and Approval of Proposed Edits*
A pre-defined process gives each partner the opportunity to review and approve the proposed edits of all other partners.

- This option will consider using ***ArcGIS Workflow Manager*** (an ArcGIS extension) as a built-in software solution for managing the workflow (see *Appendix 6b*).
- "Edit flags" and "edit dates" on proposed features will identify features to be reviewed. Partners use the display of SDE geodatabase versions and reference layers in ArcMap to visually review proposed features.
- SDE Versioning (i.e., Reconcile and Post operations), Data Comparison tools, Map and Geodatabase Topology rules and topological editing are used to discover potential conflicts among features and versions.
- In the case of disagreements regarding specific edits, a collaborative process guides the partners to resolution. A WebEx or Microsoft Lync session may facilitate this discussion.
- Partners enter their names, approval dates and comments into an "edit-tracking" table.
- Once all edits are approved by all partners, edits from all versions are reconciled and posted to the MN State default version by the **MN State Administrative Steward**.

5) *Updates to the MN State NHD*
A copy of the reconciled MN default version of NHD is copied to the GDRS to become the new read-only reference NHD dataset for all agency staff.

- The MN State Administrative Steward copies the reconciled MN default version to the GDRS.
- Improved features from <u>non-partner</u> external editors (e.g., a watershed district or consultant group) are submitted to the MN State Administrative Steward, who guides the proposed edits through the *review-conflict detection-approval* process. If approved, these edits are posted to the MN default NHD dataset.

6) *Updates to Approved Edits into the USGS Federal NHD*
The **MN State Administrative Steward** updates the USGS federal NHD dataset with edits from the reconciled MN NHD default version using the standard USGS NHD Stewardship check-in/check-out procedures and the desktop *NHDGeoEdit Tools*.

- After ~ 10 days, the USGS federal NHD dataset is submitted back to MN and incorporated by the steward into the central SDE database as a "federal version". The steward reconciles the federal version with the MN default version and the resulting (combined) reconciled version becomes the new MN version for the GDRS.

Considerations

- When NHD is placed within the SDE environment, it loses some of its functionality and is no longer considered a "true NHD". Because the *NHDGeoEdit tools* are desktop tools not designed to work within the SDE environment, partners must use standard ArcGIS topological-editing tools to edit the data. With standard tools, the free-floating tables in the NHD geodatabase (e.g., *NHDReachCrossReference*) are not maintained automatically, thus breaking potentially crucial data relationships. Some NHD-specific functions performed by the *NHDGeoEdit Tools* (e.g., such as adding Reach Codes and Permanent Identifiers to new features) are not available to the editor. Only when those edits are posted to the federal database by the MN State Administrative Steward are those relationships restored.
  - When updates are made to the USGS federal NHD dataset using *NHDGeoEdit Tools*, new Reach Codes and Permanent Identifiers for features are assigned immediately, providing the necessary *identifiers* for defining new event table data (although the *features* with these new IDs won't be available until the federal version returns to MN)
  - Edits are done on a HUC-8 basis according to an established check-out/check-in procedure. USGS Stewardship practices prevent editing conflicts by allowing only one editor to check out a single HUC-8 at a time.
  - Once the updated federal dataset is checked back into USGS, edits become available for the edited HUC-8 in 2-3 days and through a pre-staged state file geodatabase in 10 days. If we want to ensure that only a true, federally-synchronized NHD with all associated tables and relationships is distributed to the GDRS, we must wait for the federal version to return to MN before posting it to the GDRS (~ 10 days).

- Option #1 does not require that DNR reference all of its derived data to NHD as events.
  - In-house testing has shown that two of DNR's core layers (i.e., *Stream Routes with Kittle Numbers and Mile measures* and *Open Water* polygons) can be exported from Stream Route and Open Water events referenced to the MN version of NHD. The resulting layers, after some processing, have the same properties as current DNR core layers. While some initial effort will be required to create these two new processes, the DNR can continue using its standard routines to create derived products from the NHD-derived core layers without significant changes in operation. DNR would remain in control of DNR data and derived products in-house, with as little interruption to current processes as possible (*Appendix 8*).

- Option #1 is similar to the *Alaska Hydrography Database Model* (i.e., http://seakgis.alaska.edu/alaska-hydro-database) except that NHD federal edits are not incorporated back into the Alaska state default dataset.

- The timing of NHD editing, reconciliation and posting of edits to the state and federal NHD datasets may be variable by partner agency. Edits can be added to the MN default version as needed to meet frequent business needs. Conversely, proposed edits may be collected for a period of time, then reviewed, reconciled and posted to the MN default dataset in a single edit session (i.e., for example, on an annual cycle.) The proposed timing and coordination of edit processing will be based on the stated needs of the primary partners and will be governed by a defined *pre-notification-conflict resolution-approval* process.

- Partners will need to carefully track the update cycles in order to migrate their events to follow changes in the base NHD dataset.

Pros

- The centralized SDE dataset allows for direct comparison of all features and reference data layers by all partners.

- SDE Versioning (with Reconcile and Post operations), Data Comparison tools, Map and Geodatabase Topology rules and topological editing are built-in ArcGIS/SDE functionality that aids in synchronization and QA/QC efforts.

- A customized *pre-notification-conflict resolution-approval* process (perhaps implemented via ArcGIS Workflow Manager) within the shared SDE environment allows for timely review and formal tracking of proposed edits by all partners.

- Partners get frequent updates of the MN NHD reconciled dataset on the GDRS for updating core hydrography layers and derived products without needing to change current routines.

- Option #1 results in a single, statewide hydrography dataset (for streams and open water only) that meets the business needs of all partner agencies.

Cons

- This is a relatively complicated model requiring SDE administration and remote access to a centralized dataset by external partners, suggesting potential technical challenges regarding user skills, connectivity and responsiveness.

- *NHDGeoEdit Tools* are desktop tools not designed to work in the SDE environment. Edits must be repeated to the USGS federal NHD dataset by the MN State Administrative Steward using these tools.

- A customized *pre-notification-review-conflict resolution-approval* process must be developed. If ArcGIS Workflow Manager is used, there will be a steep learning curve prior to implementation.

- This workflow requires a permanent MN State Administrative Steward to perform federal NHD updates and to reconcile the federal dataset back to the MN default version.

- The need for updated derived products requires frequent review and approval by all partners, thus interrupting other work.

- Features uploaded to the USGS federal NHD take about 10 days to filter back down to reconcile with the current state MN NHD. Although edited features will already be in the state NHD, any <u>new</u> features will not have IDs assigned until after going through the federal update process. Therefore, referencing partner events to any <u>new</u> features will be delayed until the necessary features with IDs show up in the state dataset. (Other events can be migrated without waiting for the federal update process.)

Option #2:   Direct-editing to the USGS federal NHD (*Figure 6-2*)

Under Option #2, all partners use the state MN NHD (in the GDRS) as the base hydrography dataset and reference their business data directly to NHD as events. Partners use a shared web application such as ArcGIS Online (AGOL) to share, review and approve edits proposed by other partners.   Agency partners are trained and authorized as NHD "sub-Stewards" to make edits directly to the USGS federal NHD using the established NHD Stewardship check-out/check-in procedures. The MN State Administrative Steward incorporates the updated USGS federal NHD dataset into the GDRS as the new MN NHD dataset.

Highlights of this option are:

1) *Multiple Editor Environment*
   Partner editors download copies of the current MN NHD dataset from the GDRS and make proposed edits as needed.

   - Editors upload proposed edited features to a shared web application such as ArcGIS Online (AGOL) for partner review.

2) *DNR Event Referencing*
   All partners (including DNR) reference their core and derived hydrography-related data directly to the MN NHD state dataset.

   - DNR events are exported as derived products to the GDRS for access by all partner agencies.
   - DNR events are converted by *newly developed processes* to replicate current DNR derived products.

3) *Pre-notification of Intended Edits*
   Authorized partner editors notify other partners of areas where they intend to make edits.

   - Pre-notification is via email that points partners to a shared web application (such as an ArcGIS Online (AGOL) application).
   - Editors use "mark-up" tools to specify areas where edits will be made.
   - Partners can add comments and notes to intended edit areas.

4) *Review, Conflict Detection and Approval*
   A pre-defined process gives each partner the opportunity to review and approve the proposed edits of all other partners.

   - The editor uploads proposed edits to shared web application (such as an ArcGIS Online (AGOL) application).
   - Partners review proposed edits using Comment and Edit capabilities.
   - In the case of disagreements regarding specific edits, a collaborative process guides the partners to resolution. The shared web environment may facilitate this discussion.
   - Partners enter names, approval dates and comments into "edit tracking" tables.
   - External non-partner editors can submit improved features to authorized sub-Stewards , who are responsible for guiding the proposed edits through the *review-conflict detection-approval* process. If approved, these edits would be posted by a sub-Steward to the USGS federal NHD dataset (*step*

5). At some future date, the web application could be opened up to external editors for direct submission of enhanced data.

(Note: Steps 5 & 6 below are in reverse order as compared to Option #1, i.e., federal updates occur before state updates)

5) Updates to the USGS federal NHD

Once edits are approved by all partners, a partner sub-Steward directly updates the USGS federal NHD with the approved edits using the standard USGS NHD Stewardship check-in/check-out procedures and the desktop *NHDGeoEdit Tools*.

- Selected staff from each partner agency take the NHD Edit Training to be authorized as State NHD Editing sub-Stewards.

- A *primary* MN State Administrative Steward is identified as the main point of contact between the State of Minnesota and USGS.

- State-specific stewardship by-laws are written and adopted by all sub-Stewards.

6) Updates to the MN state NHD

After ~ 10 days, the updated USGS NHD federal dataset is submitted back to MN and incorporated by the State Administrative Steward into the GDRS as the new MN NHD Dataset.

- All partner events are updated ("migrated") based on the new MN NHD in the GDRS.
- Derived products are generated by newly defined automated processes.

Considerations

- When updates are made to the USGS federal NHD dataset using *NHDGeoEdit Tools*, new Reach Codes and Permanent Identifiers for features are assigned immediately, providing the necessary *identifiers* for defining new event table data (although the *features* with these new IDs won't be available until the federal version returns to MN).

- As in Option #1, edits are done on a HUC-8 basis according to an established check-out/check-in procedure. USGS Stewardship practices prevent editing conflicts by allowing only one editor to check out a single HUC-8 at a time.

- Once the updated federal dataset is checked back into USGS, edits become available for the edited HUC-8 in 2-3 days and through a pre-staged state file geodatabase in 10 days. If we want to ensure that only a true, federally-synchronized NHD with all associated tables and relationships is distributed to the GDRS, we must wait for the federal version to return to MN before posting it to the GDRS (~ 10 days).

Pros

- Partners have the flexibility to make edits as needed for their business needs without working through a single state steward. This is the quickest and most direct route for partners to get their updates into the federal NHD dataset.
- Established USGS steward procedures provide the most uniform method for all state partners to follow.
- No complicated SDE data architecture or administration is required.
- The same base NHD dataset (on the GDRS) is used by all partners; there are no business-only datasets or "versions" to consider.
- Referencing DNR data directly to the NHD framework would allow users of DNR data to take advantage of NHD-compatible tools, such as upstream tracing on the NHD flowline network.
- This option results in a single, statewide hydrography dataset (for streams and open water only) that meets the business needs of all partner agencies.

Cons

- Unlike SDE, this option doesn't provide a ready-made environment for synchronization of edited features and QA/QC.
- A customized shared web application (such as an ArcGIS Online application) must be developed for the *pre-notification-review-conflict resolution-approval* process.
- Partners need to take specialized training to become authorized MN NHD editors and sub-stewards.
- Partners (including DNR) need to reference all agency data as events on NHD.
- DNR (and possibly other partners) need to re-define the business-specific maintenance and derived product processes currently in use.
- Unlike Option #1, there is no state NHD dataset immediately available with the new edited features. Features uploaded to the USGS federal NHD take about 10 days to filter back down as a new statewide dataset to replace the current MN NHD. Referencing partner events to the updated state NHD will be delayed until the necessary features show up in the state dataset.

Option #3: Business-focused editing (Figure 6-3)

Under Option #3, partner agencies have the option of maintaining their existing enterprise hydrography datasets to meet specific business needs. Edits flow in two directions (i.e., from partners to NHD and from NHD to partners) in order to keep business datasets and NHD synchronized.

It should be noted that only DNR is considering this option, in case other options prove to be unworkable for DNR. The upcoming section describes highlights, pros and cons as they affect DNR only. The other partners would edit directly to the USGS federal NHD dataset as described in Option #2 (*see previous section*).

Highlights of this option are:

1) *Multiple Editor Environment*
MnGeo, MPCA and USFS follow the editing procedures as outlined in Option #2.

- DNR continues to maintain its existing enterprise DNR Hydrography Dataset, with its unique spatial structure and attributes, to meet specific business needs.
- DNR flags any internally-edited features in its enterprise hydrography dataset with an "edit date".
- DNR periodically compares the state NHD dataset (on the GDRS) against the DNR enterprise Hydrography Dataset and incorporates any new edits. DNR has control over when and how often these synchronization efforts are performed.

2) *DNR Event Referencing*
DNR references derived data as events on its core hydrography data layers which are derived from the enterprise dataset (i.e., current system).

- DNR events are exported as derived products for the GDRS and Minnesota Geospatial Commons using current business practices.

3) *Pre-notification of Intended Edits*
All partners follow the pre-notification procedures as outlined in Option #2.

- DNR notifies the MN State Administrative Steward of its intent to edit in a given area; the steward handles the pre-notification in ArcGIS Online for DNR.

4) *Review, Conflict Detection and Approval of Proposed Edits*
MnGeo, MPCA and USFS follow the review procedures as outlined in Option #2.

- DNR passes its internal edits to the MN State Administrative Steward for consideration under the ArcGIS Online review process. DNR is notified only if there is a "dispute" in reference to a DNR-proposed edit.
- DNR participates in the web-based review of edits proposed by other partners.

Note: It will be important for DNR to participate in the approval process for partner-proposed edits. It is much easier for DNR to negotiate a "compromise" regarding a particular feature before it ends up in the USGS federal NHD dataset rather than after. If DNR won't accept a particular edit from the NHD into the DNR Hydrography Dataset, the two datasets will not remain synchronized.

(Note: As in Option #2, Steps 5 & 6 below are in reverse order as compared to Option #1, i.e., federal updates occur before state updates)

5) *Updates to the USGS federal NHD*

- MnGeo, MPCA and USFS follow the federal NHD incorporation procedures as outlined in Option #2.
- DNR relies on the State Administrative Steward to incorporate DNR's edits into the federal NHD dataset. Edits to the NHD from the DNR Hydrography Dataset are based on the DNR's edit dates for new or modified features.

6) *Updates to the MN state NHD*

- MnGeo, MPCA and USFS follow the MN NHD incorporation procedures as outlined in Option #2.
- DNR is not reliant on the state NHD to update its event data or generate derived products
- For periodic synchronization with NHD, DNR obtains the state NHD (from the GDRS) and relies on "edit dates" and topology tools to find features that are different from DNR features.

Considerations

- This option most closely resembles the current system for the maintenance of DNR data, except that currently DNR and NHD are not actively being kept synchronized. Thus, additional efforts are required to monitor, track and update feature edits. Although DNR relies on the State Administrative Steward to incorporate its edits into NHD, DNR must still participate in the review process to approve other partner edits and to resolve conflicts as they arise.

Pros

- Option #3 is the easiest option for DNR to adopt since it is essentially the current system regarding maintenance of DNR data.
- DNR maintains total control over its enterprise hydrography dataset and related business data; no restructuring of current DNR data or automated processes is necessary.
- DNR can make real-time edits to its core hydrography and derived product layers as needed, without approval from other agency partners.
- Because it doesn't use NHD as its hydrography base dataset, DNR is not reliant on its edits to be incorporated into NHD in order to update events and create derived products.
- DNR can schedule the incorporation of NHD features into the DNR Hydrography Dataset as time and staff resources permit.

Cons

- This option requires a new, dedicated effort by DNR to keep its enterprise hydrography dataset synchronized with the MN NHD state dataset.
- It also requires more work by the State Administrative Steward to handle DNR updates to NHD and to help resolve "disputes" that arise.
- It will be difficult to "undo" partner features once they are incorporated into the USGS federal NHD dataset; thus, if DNR finds some features "unacceptable" for its enterprise dataset, the two datasets will begin to diverge.

- This option does not result in one authoritative hydrography dataset for the state, but rather, two parallel datasets (i.e., DNR Hydrography and NHD) that exist in “lagged” synchronization.

Considerations for all options

- The decision has been made to use *DNR Open Water (OW) Basins* as the base waterbody feature class for statewide synchronization with NHD (*Chapter 4*). This has several implications for DNR derived data:
  - DNR has numerous derived layers based on Open Water features. Because polygon events must be equal to or smaller than the waterbodies to which they are referenced, Open Water derived products can be maintained as polygon events upon NHD waterbodies. [Affects Options 1 & 2 only.]
  - By Minnesota Statute (*M.S. 103G.201*), DNR must maintain maps of Public Waters basins and watercourses for regulatory purposes. Geospatial data layers are used to create these maps. With Open Water as the basis for new NHD waterbodies, Public Waters basins **cannot** be referenced to NHD as polygon events because they are generally larger than Open Water. This means that <u>Public Waters Basins must be maintained as a separate hydrography feature class outside of NHD</u>.
  - The new National Wetlands Inventory (i.e., NWI, in progress 2014) is the most current source of surficial hydrography features for Minnesota. Delineations include all types of hydrographic features (including open water) classified into complex wetland codes. <u>NWI will need to be maintained as a separate polygon feature class</u> as it is currently not possible to store all NWI wetland types within NHD feature classes. Even if wetland features are eventually incorporated into the MN state NHD, it is unlikely that all wetland types found within NWI will ever be included in NHD (thus necessitating the need for a separate NWI dataset). Currently, NHD has only one feature type for wetlands (i.e., Swamp/Marsh category).

    Note: It is worth noting that USGS is exploring the possibilities of integrating NWI and NHD at the federal level.

- The federal NHD dataset is an un-projected dataset with coordinates maintained in Latitude/Longitude (i.e., GCS_North_American_1983). The State of Minnesota has a standard defined projection of UTM NAD1983 Zone 15.
  - Projecting the NHD dataset into the UTM projection breaks the linear geometric network which has to be rebuilt in order to use NHD-compatible tools (e.g., such as *Utility Network Analyst* tools for upstream network tracing).
  - For long-term maintenance, it is preferable to keep NHD un-projected to avoid the potential problems (e.g., spatial drift, connectivity errors) of repetitive projection and un-projection of the dataset.
  - Due to the small errors that occur when transferring features from projected to un-projected datasets, small levels of error (not visually detectable) must be accepted between copies of

datasets and any summaries made from them.

- All options rely on a strictly defined *pre-notification-review-conflict resolution-approval* process that allows all partners to review and approve “provisional” edits before they become finalized.
    - The *general steps* (i.e., pre-notification, conflict resolution, approval) will likely be the same for each option, although *specific details* (i.e., who, what, where, when and how) may differ among the options.
- All options involve some duplication of effort since editors need to post edits for partner approval and then repeat the edits to the federal NHD using the *NHDGeoEdit tools*. This is an unavoidable consequence of the partner approval requirement. In the future, as partners become sufficiently aware of the business needs of other agencies, the approval process for (at least some) edits may be relaxed, allowing edits to be added to NHD without partner approval.
- All options assume that the partner base datasets have been previously synchronized before a new Maintenance Model is implemented (as per *Chapter 4*). If full synchronization is achieved between NHD and partner datasets, future updates to the NHD should be considerably less and could potentially be handled as individual edits rather than via conflation.
- Each partner will need to develop procedures to address handling of event data following feature updates to the state and federal NHD datasets (*Chapter 8; Appendix 8*).
- Edits made by USGS for features outside of Minnesota borders will need to be incorporated back into the MN NHD state dataset and must be examined for conflicts with or consequences to MN data.

Discussion

A general comparison of the three options reveals that **Option #1 (*Direct editing to a central SDE MN hydrography database*)** is the most complex solution, but offers built-in tools to aid in the editing and synchronization of features. It also offers a "short-cut" (in the form of a MN reconciled NHD version) to getting approved edits into partner derived products without waiting for the USGS federal dataset to be updated and returned. However, newly added features will lack reach codes until the federal dataset is updated, so some event data (for new features only) will need to wait to be referenced.

Option #2 (*Direct editing to the USGS federal NHD*) provides the most direct, standardized process for all partners to get their edits into NHD, but requires that a customized shared web application (such as an ArcGIS Online application) be developed to accommodate review, conflict detection and approval at the state level. Waiting for edits to come back in the form of an updated federal NHD dataset may be prohibitive to business needs.

Option #3 (*Business-focused editing*) offers the most local control for DNR as it requires essentially no change to current DNR database structures or business processes for generating derived data. However, it does not result in a single statewide hydrography dataset for all MN users, but rather, in parallel datasets characterized by "lagged synchronization" at best. It will require more work from the State NHD Administrative Steward to coordinate DNR's edits into NHD. Furthermore, it will be difficult to keep the DNR Hydrography and NHD datasets truly synchronized if DNR is unable to keep up with NHD edits.

Variations

Note that for testing purposes, each Maintenance Option was designed to incorporate unique strategies to address the **essential components** of the maintenance workflow; however, these are not the only options possible. Following testing, the most feasible technical strategy for each component will be chosen and combined into a **recommended option** (see *Chapter 7*).

The essential components are discussed earlier in this document. Differences in component strategies among the three options are described in **Table 6-1** (*next page*). The component strategies can be mixed and matched to provide a unique solution. (Note that not all strategy combinations make sense and that others are inherently related.)

A hypothetical example of a final recommendation may be to:

- Have DNR reference its data to DNR core layers derived from NHD (Option 1)
- Use ArcGIS Online as a strategy to pre-notify, review and reconcile proposed edits (Option 2)
- Have a single State Administrative Steward make updates to the USGS federal dataset (Option 1)
- Have the State Administrative Steward copy the federal NHD to the MN NHD GDRS (Option 2)

Refer to *Chapter 7* for testing and results of all model options.

This table summarizes the specific technical strategies used for each component within each Maintenance Option.

Options:	**OPTION 1**	**OPTION 2**	**OPTION 3**
	Direct Editing in SDE	Direct Editing to Federal	Business-Focused (DNR only)
Components:	(DNR, MNGEO, MPCA, USFS)	(DNR, MNGEO, MPCA, USFS)	(MNGEO, MPCA, USGS) & (DNR)
1. Multiple Editor Environment	MN NHD in ArcSDE; partner-specific "EDIT" versions of NHD	All partners edit individual MN NHD (GDRS copies)	Non-DNR partners edit individual MN NHD (GDRS copies); DNR edits DNR Hydrography Dataset
2. DNR Data Referencing	To base layers derived from reconciled MN NHD	To NHD GDRS dataset as events	To DNR Hydrography Dataset features (current system)
3. Pre-notification	Email, shapefile or ArcMap bookmarks	Shared web app with mark-up (e.g., ArcGIS Online-AGOL)	Shared web app with mark-up (e.g., ArcGIS Online-AGOL)
PROPOSED EDITS			
4a. Review	ArcMap display of SDE versions and reference layers; edit flags and dates on proposed features; via WebEx/Lync or shapefile	Shared web app with mark-up (e.g., ArcGIS Online-AGOL); Editor uploads edits to AGOL; posts Notes, Comments, dates	Shared web app with mark-up (e.g., ArcGIS Online-AGOL); Editor uploads edits to AGOL; posts Notes, Comments, dates
4b. Conflict Detection	SDE Versioning (reconcile/post); Map or Geodatabase Topology; Data Comparison tools; topologic editing tools	Visual review in AGOL; partner Comment and Edit capabilities	Visual review in AGOL; partner Comment and Edit capabilities
4c. Approval	Partners enter names, approval dates, comments into "edit-tracking" table	Partners enter names, approval dates, comments into "edit-tracking" table or notes (AGOL)	Partners enter names, approval dates, comments into "edit-tracking" table or notes (AGOL)
STATE & FEDERAL UPDATES			
5. Incorporating approved edits into MN State NHD	State Administrative Steward copies reconciled MN "default" SDE version to GDRS	State Administrative Steward copies updated federal NHD to GDRS (*after step 6, below*)	**DNR:** passes edits to State Administrative Steward **Non-DNR partners:** State Administrative Steward copies updated federal NHD to GDRS (*after step 6, below*)
6. Incorporating approved edits into USGS federal NHD	State Administrative Steward updates federal NHD using reconciled MN "default" SDE version) AND posts federal updates to state NHD (two-way updating)	State sub-Stewards (all partners) make direct updates to federal NHD from "approved" edits	**DNR:** State Administrative Steward make direct updates to federal NHD from "approved" DNR edits; DNR periodically updates DNR Hydrography Dataset using GDRS NHD **Non-DNR partners:** State sub-Stewards make direct updates to federal NHD from "approved" edits

Table 6-1: *Three maintenance options and their component strategies*

References

Appendix 7a: State Communication and Coordination Plan
- describes the functional roles of communication and coordination as related to Minnesota NHD Stewardship

Appendix 7b: NHD Stewardship Process
- describes the NHD Stewardship Process as outlined by USGS

Appendix 8: DNR Event Referencing Strategies
- outlines DNR testing of referencing data to NHD as events and generating DNR derived products

Chapter 4: NHD-DNR Dataset Synchronization

Chapter 7: Maintenance Option Testing and Results

Chapter 8: Events and Event Maintenance

Minnesota Statutes (M.S.): https://www.revisor.mn.gov/pubs/ State of Minnesota, 2013.

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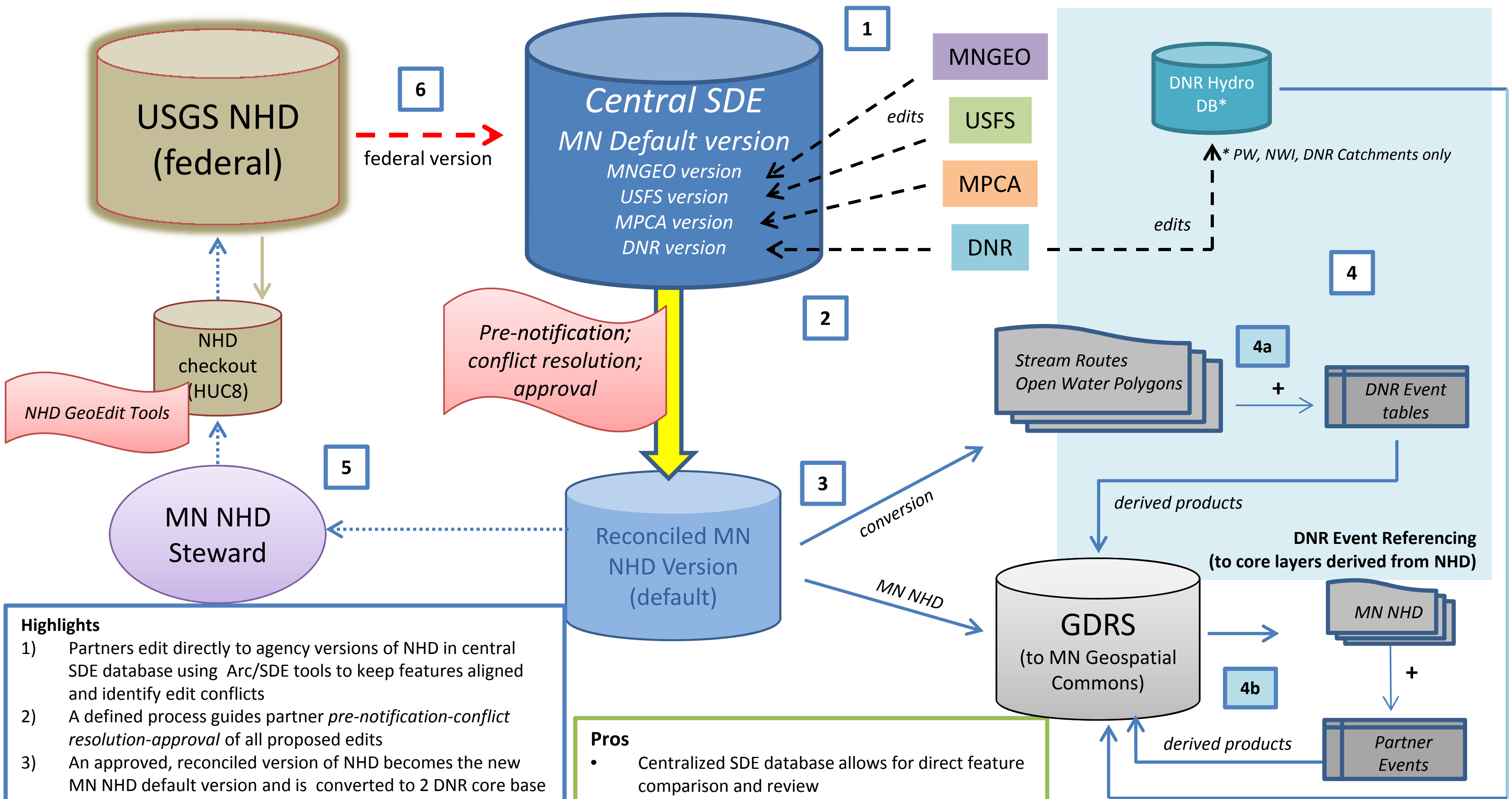
[i] Data Governance refers to the development and integration of processes, policies, standards, organization, and technologies required to leverage data as an enterprise asset. (Data Governance Winter Conference, Fort Lauderdale, FL, November 2013) http://www.debtechint.com/dgwinter2013/

Figure 6-1. Option 1: Partners edit to central SDE database



Highlights

1) Partners edit directly to agency versions of NHD in central SDE database using Arc/SDE tools to keep features aligned and identify edit conflicts
2) A defined process guides partner *pre-notification-conflict resolution-approval* of all proposed edits
3) An approved, reconciled version of NHD becomes the new MN NHD default version and is converted to 2 DNR core base layers (streams and open water). Both are exported to GDRS.
4) (a) DNR event data is referenced to core streams and OW layers to make derived products. (b) Other partner events are referenced to MN NHD (GDRS) to make derived products. All derived products are exported back to GDRS.
5) MN NHD steward makes approved updates to federal NHD
6) MN NHD steward reconciles USGS federal version edits back into MN NHD default version in SDE

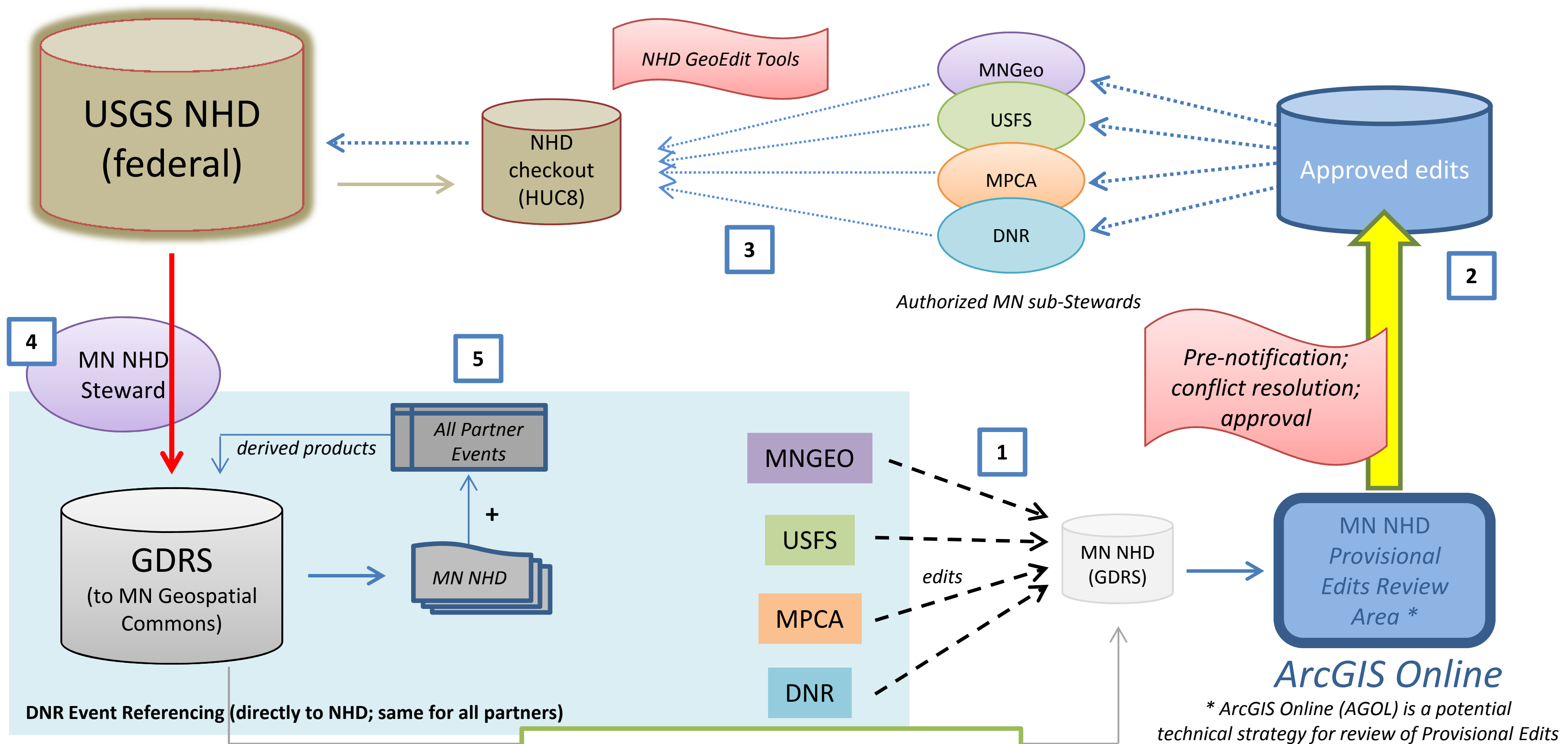
Pros

- Centralized SDE database allows for direct feature comparison and review
- Existing SDE QA structure/tools are available for editing and conflict detection
- Customized workflow process within SDE promotes timely review and approval of edits
- Frequent updates of MN NHD available for GDRS *before* updated federal version is available
- Results in a single, statewide hydrography dataset (streams, OW) that meets partner business needs

Cons

- Complicated model requiring SDE administrator
- NHD GeoEdit tools don't work in SDE, requiring 2-step update process (state and federal)
- Requires dedicated MN NHD data steward
- Need for updated derived products requires frequent partner review/approval

Figure 6-2. Option 2: All partners direct edit to federal NHD



Highlights

1) All partners edit copies of GDRS NHD layers and upload proposed edits into *"provisional edits review area"**
2) A defined process guides partner *pre-notification-conflict resolution-approval* of all proposed edits
3) Authorized partner sub-stewards make approved edits directly to USGS federal NHD via established procedures
4) An updated USGS NHD dataset is added to the GDRS by the State NHD Administrative Steward
5) All partner event data is referenced to the MN NHD (GDRS) and exported as derived products back to GDRS

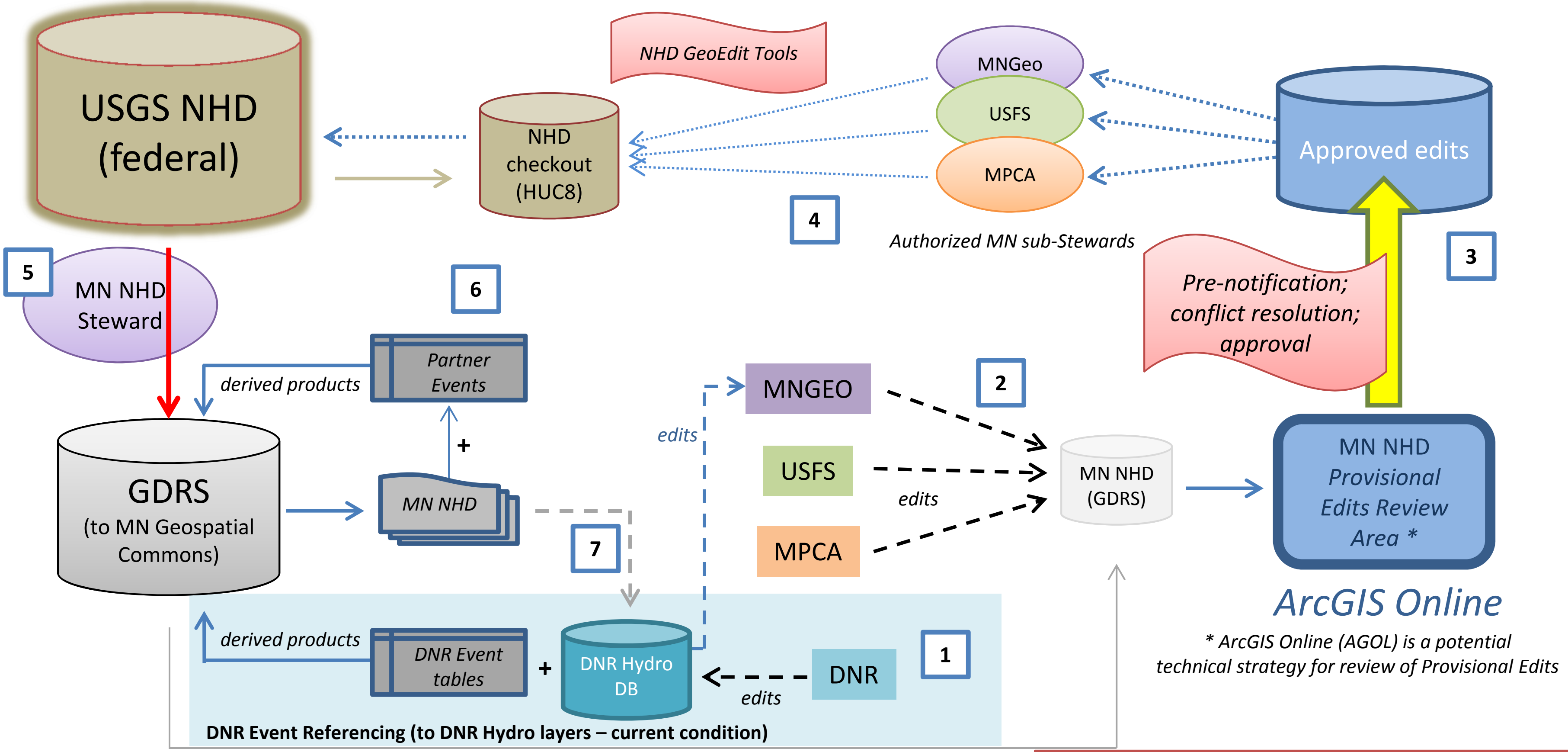
Pros

- AGOL is an easy-to-use collaborate tool for pre-notification and review of partner edits
- Partners have flexibility to make edits as needed without working through a single MN steward
- Most direct route for partners to get updates into federal NHD; established procedures
- Most uniform method for all state partners
- No business-specific versions to consider
- All partners access same base NHD from GDRS
- Results in a single, statewide hydrography dataset (streams, OW) that meets partner business needs

Cons

- Does not provide ready-made QA/QC/synchronization structure; a *"provisional edits area"** must be designed
- A customized pre-*notification- conflict resolution-approval* process must be developed without built-in tools
- Partners need NHD training to become sub-stewards
- All partners need to reference data as events on NHD
- Partners may need to re-define current business-specific maintenance and derived product processes
- Features from federal NHD will take time to filter back to GDRS reference version, thus delaying derived layers

Figure 6-3. Option 3: Business-Focused Editing (DNR only)



Highlights

1) DNR edits/maintains current Hydrography Dataset and sends derived products to GDRS; sends edits to MNGeo
2) Non-DNR partners edit copies of NHD (GDRS); upload proposed edits into *"provisional edits review area"**
3) A defined process guides partner *pre-notification-conflict resolution-approval* of all proposed edits
4) Authorized partner sub-stewards make approved edits to USGS federal NHD using check-out procedures & tools
5) MN Steward adds updated USGS NHD dataset to GDRS
6) Non-DNR partner event data is referenced to MN NHD (GDRS) and exported as derived products back to GDRS
7) DNR updates Hydro Dataset with new NHD features

Pros

- Allows most control over business data (DNR)
- Requires least change for DNR data and processes (is essentially current system for DNR)
- No waiting for DNR updated features to appear in NHD layers (real-time edits)
- Partners have flexibility to make edits as needed without working through a single MN steward
- Most direct route for partners to get updates into federal NHD; established procedures

Note: Only DNR is affected by business-focused editing. Other partners have opted for direct editing to federal NHD (same as in Option 2)

Cons

- Does not provide ready-made QA/QC/synchronization structure; a *"provisional edits area"** must be designed
- A customized *pre-notification- conflict resolution-approval* process must be developed without built-in tools
- Requires additional work by DNR to keep in sync with NHD; results in "lagged" synchronization of 2 datasets
- Does not result in a single hydrography dataset for MN

Chapter 7a: Option #1 Testing and Results

Option #1: Direct editing to a central SDE MN hydrography dataset

Description

Under Option #1, state agency partners edit directly to agency-specific “edit-versions” of NHD within a centralized SDE database maintained at the state level. SDE versioning, topology rules and topological-editing tools are used to achieve feature synchronization and detect conflicts among edits. A State NHD Administrative Steward reconciles approved edits into the state NHD dataset (default version) and uses established NHD processes to update the USGS federal NHD dataset. (See *Chapter 6* for more details.)

Objective

The objective of this test plan was to answer the following questions:

- Can we set up a centralized hydrographic SDE geodatabase that:
    - Contains the necessary data layers along with versioning, geometric networks and topologic relationships?
    - Can be accessed by our state hydrography partners (i.e., DNR, MPCA and USFS)?
    - Allows partners to create and set permissions for their own “edit- versions” of the NHD geodatabase created from the MN default version?
    - Can be edited by our partners using topologic editing methods?
    - Allows our partners to reconcile and post edits from their own version back up to the default version?
    - Allows our partners to delete their own version from the central SDE geodatabase?
    - Allows the DNR to derive measured core DNR Hydrography layers (i.e., *Streams with Measured Kittle Routes and Mile Measures* and *Open Water* polygons) from the central SDE geodatabase?
    - Can we estimate the staff and equipment resources needed for this option? (see ***Tables 7-1a, b***)

Procedural Details & Analysis

Setup

SDE Administration

A test SDE geodatabase (ArcGIS 10.2) was created by the database administrator at MnGeo on one of its servers. A feature dataset was created within that geodatabase and registered as versioned (default). A secure external access port for specific users was established.

Data

The following most currently available layers were loaded into the feature dataset within the test SDE geodatabase. These are layers most likely to be used either in the actual maintenance of Minnesota hydrographic data or as reference data. (*Note:* all were statewide in scope except for the new National Wetlands Inventory (NWI, in progress 2014), which covered only the Twin Cities metro area.)

DNR River and Stream Centerlines (Stream Type)
Data path: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\water_dnr_hydrography \water_dnr_hydrography.gdb
Feature Class: dnr_rivers_and_streams (linear features)
Layer: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\water_dnr_hydrography\Stream Routes with Stream Types.lyr
(*Quick Layer: Hydrography\Stream and River Centerlines\ Stream Routes with Stream Types*)

Stream Routes with Kittle Numbers and Mile Measures
Data path: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\water_measured_kittle_routes \water_measured_kittle_routes.gdb
Feature Class: streams_with_measured_kittle_routes (measured route features)
Layer: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\water_measured_kittle_routes\Stream Routes with Kittle Numbers and Mile Measures.lyr
(*Quick Layer: Hydrography\Stream and River Centerlines\Stream Routes with Kittle Numbers & Mile Measures*)

DNR Hydrography - All Water Features
Data path: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\water_dnr_hydrography \water_dnr_hydrography.gdb
Feature Class: dnr_hydro_features_all (polygons including open water lakes, ponds, some wetlands, artificial basins, intermittent features, 2-D river features)
Layer: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\water_dnr_hydrography\DNR Water Features.lyr
(*Quick Layer: Hydrography\Lakes and Open Water\DNR Water Features*)

Minnesota Public Waters
Data path: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\water_mn_public_waters \water_mn_public_waters.gdb
Feature Class: public_waters_basin_delineations (polygons)
Feature Class: public_waters_watercourses_delineations (linear features)
Layer: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\water_mn_public_waters\ Minnesota Public Waters Delineations.lyr
(*Quick Layer: Hydrography\Public Waters\Minnesota Public Waters Delineations*)

National Wetlands Inventory - NWI Circular 39 Classification (2009-2014) – *Twin Cities extent only*
Data path: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\water_nat_wetlands_inv_2009-2014\fgdb\water_nat_wetlands_inv_2009-2014.gdb
Feature Dataset: ECMN_NWI_UTM
Feature Class: EC_MN_NWI_UTM (polygons)
Layer: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\water_nat_wetlands_inv_2009-2014\fgdb\NWI Circular 39 Classification (2009-2014).lyr
(*Quick Layer: Hydrography\National Wetlands Inventory\ NWI Circular 39 Classification (2009-2014))*

DNR Watershed Suite - DNR Level 08 - Catchment Dataset
Data path: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\geos_dnr_watersheds\fgdb \geos_dnr_watersheds.gdb
Feature Class: dnr_watersheds_dnr_level_08_all_catchments (polygons)
Layer: <gdrs_drive>:\gdrs\data\pub\us_mn_state_dnr\geos_dnr_watersheds\fgdb\DNR Watershed Suite.lyr
(*Quick Layer: Hydrography\Watersheds\DNR Watershed Suite*)

NHD (National Hydrography Dataset)
MNGeo: NHDFlowline (entails geometric network), NHDWaterbody, NHDArea

WBD (Watershed Boundary Dataset)
MNGeo: WBD_HU8, WBD_HU10, WBD_HU12

Topology Rules

Topology governs the geometric relationships between features. These hypothetical topology rules were set up for the test feature dataset. (Actual hydrographic feature maintenance may entail different rules.)

Lakes-Waterbodies

1. DNR Open Water polygons (dnr_hydro_features_all) *Must Be Covered By* NHDWaterbody polygons (Lake/Pond type)
2. NHDWaterbody polygons *Area Boundary Must Be Covered By Boundary of* public_waters_basin_delineations polygons (as PWI basins may be made up of both Lake/Pond & Swamp/Marsh type NHDWaterbodies; note, there will be many cases where there is no PW basin for a waterbody)

Streams-Rivers

1. NHDFlowlines *Must Be Covered by Feature Class of* dnr_rivers_and_streams (DNR Stream Types with Kittle Numbers, Mile Measures, and Stream Types) lines

Test Process (Workflow)

The designated testers from each partner agency were instructed to perform the following procedures and note any problems, questions or comments they encountered.

1. Start and maintain a **connection** with MnGeo's SDE NHD test dataset (MnGeo, DNR)

2. Apply **topology** rules to the dataset (MnGeo)

3. Create their own **child version** of NHD from the default geodatabase version (DNR)

    a. **Register dataset as versioned** without the option to move edits to base because data does participate in a network and topology (DNR)

    b. Set access to one of three **permission levels** (DNR's choice):

        1. **Private**: Only the owner or the geodatabase administrator may view the version and modify versioned data or the version itself.
        2. **Protected**: Any user may view the version, but only the owner or the geodatabase administrator may edit datasets in the version or the version itself.
        3. **Public**: Any user may view the version. Any user who has been granted read/write (update, insert, and delete) permissions on datasets can modify datasets in the version.

4. Perform random **edits** to data while using the **Topology** toolbar (DNR)

5. **QA & correct** their work using **Topology** toolbar (DNR)

6. **Reconcile** and **post** changes from their version of NHD back to the default version

    a. **Perform a test case** with known conflicts due to coincident edits of the same feature by MnGeo (DNR, MnGeo)
    b. **Review** conflict editing process (DNR, MnGeo)

7. **Delete** their child NHD version (DNR)

8. Convert existing DNR core layers (i.e., *Stream Routes with Kittle Numbers and Mile Measures* and *DNR Open Water* polygons) to events on NHD

9. **Derive** new measured kittle routes and open water polygon layers from NHD default version (DNR)

Results

All the steps of the Test Process were performed with affirmative results. Partners were able to successfully perform all steps outlined in the Test Process (above). All questions under Objective were answered positively.

In addition, the following observations were made:

- The connection speed between DNR and MnGeo's geodatabase server varied noticeably during the course of the day and week; thus, editing in SDE may need to be scheduled for "off-peak" periods for efficiency. Also, it appears that network firewall issues between agencies will need to be resolved to enable connectivity in some cases.

- During the **Reconcile** operation to upload edits to the default NHD dataset, "conflict errors" are generated only when the same feature in the two datasets is edited. The user can then review the "before" and "after" features and choose which one to keep. Edits that are not made to coincident features are not flagged as conflicts by Reconcile.)

- Because no NHD feature is exactly the same as its corresponding DNR feature (see *Chapter 3*), the topology rules set up for the test were of little use since everything was reported as an error. However, once synchronization of the two datasets is completed (see *Chapters 4 & 5*), topology validation can be used to verify that geometric business requirements are being followed during editing.

- The ArcToolbox tool *Data Management: Data Comparison* was useful for comparing partner edit-versions of NHD against the default version (i.e., for finding non-coincident errors).

    - This tool compares multiple standard categories of differences among feature classes (e.g., FID geometry, length, etc., including all attribute fields) and summarizes the differences by Object ID. This tool requires that features have the same common ID in order to be compared; thus, they must be derived from the same parent dataset. (The *Permanent_ID* can be used for this comparison.)

- DNR was able to derive its two core hydrography feature classes (i.e., *Streams with Kittle Numbers and Mile Measures* and *Open Water* polygons) from the central SDE feature classes (i.e., NHD flowlines and NHD waterbodies, respectively). See *Appendix 8* for a full description of this process.

- DNR streams and open water features are represented in NHD and could be maintained within a single, centralized NHD dataset. However, we discovered that Public Waters Basins, NWI wetlands, DNR Catchments and islands **do not have comparable feature types** within NHD; thus, these features must be maintained as separate feature classes outside of NHD. To keep the features in these layers synchronized with the open water and stream features stored within NHD, topological relationships could be defined between these feature classes and an NHD dataset copy.

Conclusion

Using a remote, centralized SDE geodatabase with versioning and topology for storing and editing state hydrography data by multiple agencies is feasible. Unstable remote connections and speed variations will have to be further investigated, however, since these could limit productivity for some users. Also, since the Reconcile operation flags only those same features that were also changed in other versions as conflicts, another method for detecting changes between versions will have to be used. The ArcToolbox *Data Management: Data Comparison* tool was found to be a potential solution for finding changes among NHD versions. Although not tested here, the *ArcGIS Workflow Manager* extension is being considered as a solution for managing the maintenance workflow (see *Appendix 6b*).

Although DNR streams and open water features are represented in NHD and could be maintained within a single, centralized NHD dataset, other features (specifically Public Waters basins, NWI wetlands, DNR Catchments and islands) must be maintained as separate feature classes outside of NHD. Additional maintenance routines would need to be defined to ensure spatial consistency with related features in NHD.

References

Appendix 6b: ArcGIS Workflow Manager
- an overview of ArcGIS Workflow Manager for Maintenance Option #1

Appendix 8: DNR Event-Referencing Strategies
– outlines DNR testing of referencing data to NHD as events and generating DNR derived products

Chapter 3: Differences between the NHD and DNR Datasets

Chapter 4: NHD-DNR Dataset Synchronization (includes Resource Estimate)

Chapter 5: Synchronization Pilot Test – Process and Results

Chapter 6: Maintenance Options

Chapter 7 (a-c): Option Testing and Results

Option 1: Resource Estimate

Option #1: Partner direct editing to a central SDE MN hydrography dataset

The resource estimate for Option 1 is split into two parts. The first table below shows the one-time initial set up resources and their costs. The second shows the weekly recurring costs of each of the resources required.

Task	Staff Resource Costs	Non-staff Resource Costs
Configure central SDE server & remote secure access ports[2,3]	SDE DB Administrator (8 hours)	Virtual SDE server (pre-existing)
Upload and verify data to central SDE server[2,3]	SDE Administrator (16 hours)	ArcGIS (pre-existing)
Create notification, conflict resolution and approval workflow using Workflow Manager[2,3]	SDE Administrator (80 hours) [2, 3]	ArcGIS Workflow Manager Extension (part of ELA); ArcGIS Workflow Manager for Server (part of ELA)
DNR references events to NHD (core)[3]	DNR Editor (24 hours) [2, 3]	ArcGIS (pre-existing)
DNR re-creates two core layer scripts[3]	DNR Programmer (24 hours) [2, 3]	ArcGIS/Python (pre-existing)
Totals	**SDE Administrator (96 hours)** **SDE DB Administrator (8 hours)** **DNR Editor + Programmer (48 hours)**	**None (outside of what we already pay)**
	152 hours total	

Table 7-1a. *Setup one-time costs*

Task	Staff Resource Costs	Non-staff Resource Costs
Central SDE Administration[2, 3]	SDE Administrator (1 hour) SDE DB Administrator (1 hour)	MN.IT-maintained server
Editing MN NHD data (“edit-version”); reconcile/post to SDE default[2, 3]	GIS Editors (2 hours x 3 agencies)[2, 3] DNR Editors (2 hours)	ArcGIS (pre-existing)
Pre-notification, review, conflict resolution, approval	GIS Editors (1 hour x 3 agencies) DNR Editors (1 hour)	Webex or Lync for meetings if needed (pre-existing)
Export reconciled NHD to GDRS[2, 3]	MN Steward (2 hours) [2, 3]	ArcGIS/Python (pre-existing)
Event management	GIS Editors (1 hour x 3 agencies) DNR Editors (1 hour)	ArcGIS (pre-existing) or NHD HEM tools (free download)
DNR derived layer management	DNR Editors (2 hours)	ArcGIS/Python (pre-existing)
MN Steward updates federal NHD[2, 3]	MN Steward (8 hours)[2, 3]	NHD GeoEdit Tools (no cost)
MN Steward reconciles USGS edits* to SDE[2, 3]; updates NHD on GDRS	MN Steward (2 hours)	ArcGIS/ (pre-existing)
Totals **(per week)**	**SDE Administrator (1 hour)** **SDE DB Administrator (1 hour)** **GIS Editors (12 hours)** **DNR Editors (6 hours)** **MN Steward (12 hours)** [2, 3]	**MN.IT-maintained server; Webex/Lync; Does not include incidental, free or already-paid-for resources (e.g. travel time, ArcGIS licenses)**
	32 hours/week; 1664 hours/year	

Table 7-1b. *Recurring costs per week*

NOTE: GIS/DNR Editor hours will vary greatly depending upon data needs and staffing

[2,3] Item represents a major difference in task or total hours compared to [2]Option 2 or [3]Option 3

Chapter 7b: Option #2 Testing and Results

Option # 2: Partner direct edit to NHD; AGOL as pre-notification and review strategy, DNR Event Referencing to NHD

Description

Under Option #2, all partners use the MN NHD (from the GDRS) as their base hydrography dataset and reference their business data directly to the NHD as events. Partners use a shared web application such as ArcGIS Online (AGOL) to pre-notify, share, review and approve proposed edits. Agency partners are trained and authorized as NHD "sub-Stewards" to make edits directly to the USGS federal NHD via the established NHD Stewardship check-out/check-in procedures. The MN State Administrative Steward incorporates the updated USGS federal NHD dataset into the GDRS as the new MN NHD dataset. (See *Chapter 6* for more details.)

Objective

The objective of this test plan was to answer the following questions:

I. **Pre-notification, review, and approval:** (all partners)
   - Can an AGOL site be set up to be accessible by all editing partners?
   - Does AGOL work as a viable strategy for pre-notification and review of edits by all partners?
   - Are all partners able to access AGOL to review edits and use mark-up tools?
   - Are all partners able to make comments and propose alternative edits?
   - Are all partners able to mark their approval signature and dates for proposed edits?

II. **DNR Event Creation: referencing DNR core and derived data directly to NHD:** (DNR)
   - Is DNR able to reference DNR data (core and derived products) as events directly to NHD using standard ArcMap tools and/or NHD Hydrologic Event Management (HEM) tools?
   - Is DNR able to export derived products that match existing DNR products?

III. **The NHD Stewardship and Federal NHD Update Process:** (all partners)
   - Are all partners able to make updates directly to the federal NHD using *NHDGeoEdit* tools?
   - Are all partners able to use the USGS *Hydrologic Event Management (HEM)* tool to reference and update their event data on NHD?

   Can we estimate the staff and equipment resources needed for this option? (See ***Tables 7-2a, b***)

Each of the three numbered groups in **bold** (above) was tested by the necessary partners. Setup, testing procedures and results are summarized separately for each group (below).

I. Pre-Notification, Review and Approval (using ArcGIS Online – AGOL)

Overview

Maintenance Option #2 (*Chapter 6*) proposes using a shared web application such as **ArcGIS Online (AGOL)** as a strategy for pre-notification and review of proposed edits to NHD.

Specifically, AGOL would be used:

1) To pre-notify partners that editing work will be done in a given area and/or to specific features (e.g., by HUC8; within Superior National Forest; ditches in Beltrami County, etc.)

2) For multiple partner review, mark-up and approval of provisional edits that are uploaded to AGOL by an editing partner

Editors would use the Map Notes layer to denote specific areas where edits will be done (i.e., pre-notification). Proposed edited features could be uploaded via shapefiles for review by other partners. By using customized programming and web services, it may be possible to add a pre-built background geodatabase that users could upload proposed features to. Reviewers could look at proposed edited features in relation to other layers and imagery, and add any comments or questions to the map using mark-up tools. Reviewers would indicate their approval by signing and dating attribute fields within the shapefile or geodatabase.

Setup

A shared web mapping application was created using ArcGIS Online (AGOL) for testing purposes. High-resolution NHD was loaded as a read-only Web Map Service with ESRI's user-selectable topographic base map as background. A *Map Notes* layer was added that allowed users to add points, lines, polygons and attributes denoting portions of NHD they intended to edit. The AGOL application was then shared with a custom AGOL group composed of selected staff from MnGeo, USFS, MPCA and the DNR to do general usability testing.

Test Process (Workflow)

Users were asked to test the application and give their feedback as to how useful the AGOL may be for pre-notification and review of proposed edits among NHD Minnesota partners. No test script or set process was followed; all data and review were made up for testing purposes. In general, we were trying to demonstrate that the following steps were possible:

- MnGeo develops a test ArcGIS Online (AGOL) web application for notification and review purposes.
- Editing partners use AGOL to mark areas for intended edits (i.e., pre-notification).
- Other partners review pre-notification areas in AGOL and make comments using "mark-up" tools.
- Editors upload proposed edited features via shapefile to AGOL for review by other partners.
- All partners review proposed edits, make comments and mark their approval by signing and dating feature attributes or *Map Notes*.

Results

Partners were able to successfully perform all steps outlined in the Test Process (above). Feedback regarding ArcGIS Online (AGOL) was generally positive, with a few specifics below:

- The AGOL site was easy to set up and use, with an intuitive user interface and mark-up tools.
    - Without any prior instruction, testers were able to delineate "pre-notification" areas for intended edits and use mark-up tools.
- The *Map Notes* layer automatically stores the username and timestamp for a given feature of the person who created it, which is useful for tracking purposes.
- Testers were able to upload proposed edits to the AGOL site via zipped shapefiles.
    - It was possible to edit both the geometry and attributes of shapefiles uploaded by others (as well as the *Map Notes*) as long as they are shared to the group editing them. This includes adding fields to its attribute table for tracking edit status and comments.
    - We are investigating the possibility of loading a pre-built "Provisional Edits" geodatabase to the AGOL background to which users can upload features and edit attributes. We did not set this up for the test environment; however, consultation with DNR mobile programming staff indicates that this idea is possible through use of ArcGIS services and programmed functionality.
    - An advantage of having a pre-built background geodatabase for provisional edits is that it serves as a long-term archive of all proposed edits and their approval status. Domains limiting inputs to fields (i.e., drop-down lists) may also be implemented to standardize data.
- AGOL requires much less administrative overhead than SDE (Option #1) and could be expanded to add more categories of users with different privileges (e.g., external non-partners that have improved features to contribute; requests for special editing).

II. DNR Event Creation: Referencing DNR core and derived data to NHD

Overview

All partners need to be able to reference their business-specific hydrography data directly to NHD as events using the USGS *Hydrography Event Management (HEM)* tool or generic ArcGIS *Linear Referencing* tools. MPCA and USFS already create and maintain events on NHD using the HEM tool; thus, this particular test was performed by DNR staff only.

Setup

USGS Hydrologic Event Management (HEM) tools for ArcMap 10.1 were downloaded from the USGS website (http://nhd.usgs.gov/tools.html) and installed on individual tester PC's. Testers used the MN state NHD dataset (from the GDRS) and DNR event data for testing tool functionality.

Test Process (Workflow)

DNR tested the ability to reference DNR hydrography data directly to NHD as events and generate derived products that are comparable to the current products being served on the GDRS. Specifically, DNR tested the following:

- Event creation:
  - referencing current hydrography data layers as events directly to NHD
  - generating event tables for DNR data
  - displaying event table data on NHD
  - exporting displayed events to produce derived product layers for the GDRS

- Event management:
  - adding, deleting, editing and migrating DNR event data following changes in underlying NHD feature geometry

The DNR testing process was fairly comprehensive; the process and results are fully documented in *Appendix 8*. Some key results are listed below.

Results

- DNR was able to successfully reference its core and derived products to NHD, although for streams-related and open-water related products only (see *Appendix 8*).

  - DNR was able to use both standard ArcGIS tools and USGS HEM tools to reference and update its event data (*Appendix 8*).

  - By having its data referenced directly to NHD rather than maintaining its own enterprise hydrography dataset, DNR loses some control over the base hydrographic features but benefits from feature improvements made by other agencies incorporated into NHD. Disagreements over feature edits are worked out during the review process.

  - With its data referenced directly to NHD, DNR can use the network functionality within the NHD flowline dataset in relation to its data (e.g., possible analyses include upstream/downstream tracing by stream order; barrier modeling of DNR designated trout streams, etc.)

III. NHD Stewardship Process

Overview

A strong stewardship program (including a permanent primary **State Administrative Steward** as well as multiple partner sub-Stewards) is necessary for the success of this option.

To support NHD Stewardship, the USGS manages the overall NHD hydrography framework and program. USGS maintains the national version of the database, and the stewardship process manages updates to the data that come from a large number of federal, state, and local partners. USGS defines and evolves the data model, stores and distributes the master NHD database, develops NHD editing tools, performs quality control checks that maintain the integrity of the data model, and manages the flow of updates to the national data set.

USGS works with a principal Administrative Steward in each state, but leaves it up to the states how they choose to coordinate editing as sub-Stewards. The NHD Stewardship process as established by the USGS NHD Team is fully described in *Appendix 7b*. In a related topic, *Appendix 7a* describes a proposed *State Communication and Coordination Process* that partnering agencies in Minnesota could use as joint editors of the NHD.

Direct Editing to USGS federal NHD

Note that direct editing to the USGS federal NHD dataset was not specifically tested by partners because federal update processes are already well-established and are known to work. Partners will need specific training before being authorized as direct editors to NHD. However, given the established NHD edit processes and tools, and past experience of some editors, sub-Stewards should be able to successfully edit directly to the USGS federal NHD.

In Minnesota, the NHD Stewardship check-out and notification process is a known process that has been used in the past by MnGeo as the acting Minnesota NHD State Administrative Steward. It has also been used successfully by numerous NHD stewards across the U.S.

Neither is there a need to test the basic NHD editing tools. The ***NHDGeoEdit*** tool is available from the USGS website http://nhd.usgs.gov/tools.html. There has been broad experience nationwide using this tool and MnGeo has used the *NHDGeoEdit* tool extensively for production NHD edits. The MPCA and the U.S. Forest Service Minnesota National Forest staff have had training on the *NHDGeoEdit* tool and have performed test edits. An updated tool for ArcGIS 10.2 is expected in late 2014. (See *Chapter 5* for more information on the *NHDGeoEdit* tools.)

Results

- The concept of "stewardship" needs to be understood in regards to long-term NHD maintenance, but was not specifically tested here. A strong NHD Stewardship program exists to support states in maintaining and coordinating the NHD dataset at the state level.
- Both a State Administrative Steward and multiple partner sub-Stewards are necessary for Option #2. Minnesota partnering agencies may want to follow the proposed *State Communication and Coordination Process* for joint management of the state NHD (*Appendix 7a*).
- Although not specifically test here, sub-Stewards are expected to be able to successfully edit directly to the federal NHD using USGS *NHDGeoEdit* tools.

Conclusion

ArcGIS Online (AGOL) is a promising strategy for the pre-notification, review, conflict detection and approval of proposed edits by editing partners. Because this process is so essential to creating products that meet the business needs of all partners, an easy and flexible solution is strongly desired.

DNR is able to successfully recreate its derived products for the GDRS from data referenced directly to NHD, although it will need to develop new business practices and re-write automated processes. The initial conversion of DNR data to NHD events will be a large, one-time effort. However, the ongoing maintenance of DNR hydrography data as events will add significantly to the workload of DNR staff.

Major agency partners want the ability to edit directly to the USGS federal NHD dataset. Because USGS procedures are well-established and custom tools and training are available, this should be a very viable option. A strong stewardship program (including a dedicated State Administrative Steward and multiple sub-Stewards) will be necessary to success, as will a well-developed *State Communication and Coordination Process.*

As in Option #1, it was determined that DNR streams and open water features are similarly represented in NHD and could be maintained within a single, centralized NHD dataset. However, Public Waters Basins, NWI wetlands, DNR Catchments and islands do not have comparable feature types within NHD; thus, these features must be maintained as separate feature classes outside of NHD.

References

Appendix 7a: State Communication and Coordination Plan
- describes the functional roles of communication and coordination as related to Minnesota NHD Stewardship

Appendix 7b: NHD Stewardship Process
- describes the NHD Stewardship Process as outlined by USGS

Appendix 8: DNR Event-Referencing Strategies
– outlines DNR testing of referencing data to NHD as events and generating DNR derived products

Chapter 5: Synchronization Pilot Test – Process and Results

Chapter 6: Maintenance Options

Chapter 7 (a-c): Option Testing and Results

Option 2: Resource Estimate

Partner direct edit to USGS NHD; AGOL as pre-notification and review strategy

The resource estimate for Option 2 is split into two parts. The first table below shows the one-time initial set up resources and their costs. The second shows the weekly recurring costs of each of the resources required.

Task	Staff Resource Costs	Non-staff Resource Costs
Configure ArcGIS Online (AGOL) web application & editor access[1]	AGOL Administrator (8 hours)	AGOL account (pre-existing)
Create AGOL service(s)[1]	AGOL Programmer (16 hours)	
Connect AGOL and data services[1]	AGOL Administrator (8 hours)	
Create notification, conflict resolution and approval workflow	AGOL Administrator (16 hours)[1]	
Create "provisional edits" geodatabase[1]	GIS Editor (8 hours)	ArcGIS (pre-existing)
Customize web application[1]	AGOL Programmer (24 hours)	AGOL account (pre-existing)
DNR references events to NHD[3]	DNR Editor (80 hours)[1,3]	ArcGIS (pre-existing)
DNR re-create derived product scripts[3]	DNR Programmer(80 hours)[1,3]	ArcGIS/Python (pre-existing)
Totals	**AGOL Administrator (32 hours)**[1] **AGOL Programmer (40 hours)** **GIS Editor (8 hours)** **DNR Editor + Programmer (160 hrs)**[3]	**None (outside of what we already pay)**
	240 hours total	

Table 7-2a. *Setup one-time costs*

Task	Staff Resource Costs	Non-staff Resource Costs
Maintaining AGOL site[1]	AGOL Administrator (1 hour) AGOL Programmer (1 hour)	MN.IT-maintained server
Editing MN NHD data (GDRS copy)[1]	GIS Editors (2 hours x 3 agencies)[1] DNR Editors (2 hours)	ArcGIS (pre-existing)
Pre-notification, review, conflict resolution, approval	GIS Editors (1 hour x 3 agencies) DNR Editors (1 hour)	Webx or Lync for meetings if needed (pre-existing)
Sub-Stewards update federal NHD[1]	Sub-Stewards (2 hours x **4** agencies)[3]	NHD GeoEdit Tools (no cost)
Event management	GIS Editors (2 hours x 3 agencies) DNR Editors (2 hours)[3]	ArcGIS (pre-existing) or NHD HEM tools (free download)
DNR derived layer management	DNR Editors (1 hour)	ArcGIS/Python (pre-existing)
MN Steward copies USGS copy to GDRS	MN Steward (1 hour)	ArcGIS/ (pre-existing)
Totals	**AGOL Administrator (1 hour)** **AGOL Programmer (1 hour)** **GIS Editors (15 hours)** **DNR Editors (6 hours)** **MN Steward (1 hour)**[1, 3] **Sub-Stewards (8 hours)**[1, 3]	**MN.IT-maintained server; Webex/Lync; Does not include incidental, free or already-paid-for resources (e.g. travel time, ArcGIS licenses)**
	32 hours/week; 1664 hours/year	

Table 7-1b. *Recurring costs per week*

NOTE: GIS/DNR Editor hours will vary greatly depending upon data needs and staffing

[1,3] Item represents a major difference in task or total hours compared to [1]Option 1 or [3]Option 3

Chapter 7c: Option #3 Testing and Results

Option # 3: Business-focused editing and lagged synchronization to NHD

Description

Under Option #3, DNR maintains its existing enterprise DNR Hydrography Dataset to meet specific business needs. Edits flow from DNR to NHD via the State Administrative Steward. DNR still participates in the review of other partner-proposed features via ArcGIS Online. DNR periodically updates its hydrography dataset with the NHD dataset to maintain a "lagged synchronization" with NHD. (See *Chapter 6* for more details.)

Other partners follow the methods as outlined under Option #2 (i.e., edits to state NHD, review via AGOL, direct editing to federal NHD). Refer to *Chapter 7: Option #2 Testing and Results* for test details.

Objective

The objective of this test plan was to answer the following questions (affecting <u>DNR only</u>):

- Can DNR get its edits incorporated into the federal NHD via the State Administrative Steward or another sub-Steward?
- How does DNR review and approve NHD edits proposed by other partners?
- Can DNR identify updates in the state and federal NHDs (by edit date or other means)?
- Can DNR make timely updates to the DNR Hydrography Dataset to achieve an acceptable "lagged synchronization" with NHD?
- Do the benefits of maintaining the DNR Hydrography Dataset for DNR business needs outweigh those of having a single, centralized hydrography (NHD) dataset?
- Can we estimate the staff and equipment resources needed for this option? (see ***Tables 7-3a, b***)

Procedural Details & Analysis

Setup and Data

Setup for non-DNR partners (i.e., MnGeo, MPCA and USFS) is described in Option #2: Testing and Results. Setup for DNR is the same as the current enterprise system, i.e., DNR maintains its enterprise geospatial DNR Hydrography Dataset using current business practices (see *Chapter 1c*).

Test Process (Workflow)

DNR testers were instructed to perform the following procedures and note any problems, questions or comments they encountered. Only the steps unique to Option #3 (DNR only) were tested here. For non-DNR partner testing, refer to Option #2.

1. Review GDRS NHD feature classes to identify recent updates (via *Fdate* or other attributes).
2. Use standard ArcMap tools to update DNR Hydrography feature classes to match NHD.

3. Update DNR attributes to track feature update dates and source (i.e., NHD).

4. Develop summary statistics to test consistency among corresponding DNR and NHD feature classes.

Results

DNR was able to successfully perform all of the steps of the Test Process.

In addition, the following observations were made:

- Statistical summaries of NHD and DNR feature classes (e.g., total sum length of streams; total acreage of lakes, etc.) matched within an acceptable error.
  - When NHD is projected into UTM NAD 1983 Zone 15 (to match the DNR Hydrography Dataset), there is rounding error that occurs. None of the features between the two datasets are ever exactly coincident; thus the summaries will never be exactly equal either.
  - Because NHD data extends beyond the Minnesota state boundary, NHD layers must be first clipped to the state boundary before comparison with DNR is possible.

Conclusion

For non-DNR partners (MnGeo, MPCA and USFS), see conclusions for Option #2. This option will require additional work (as compared to Option #2) on the part of the State NHD Administrative Steward to move DNR's edits through the review system, resolve disputes that may arise and incorporate those edits into the federal NHD.

This option results in the least change for DNR as it continues to maintain its enterprise hydrography dataset and derived products using current procedures. This option assures that DNR can produce the products it needs for business operations without giving up any control of its geospatial data. In addition, DNR benefits from feature improvements made by other agencies incorporated into NHD.

However, this option will require a dedicated effort by DNR to keep its enterprise dataset synchronized with the MN NHD dataset. The formalized process for review of provisional edits will ensure that the features incorporated into NHD by other partners are compatible with DNR business needs.

An opportunity for statewide interagency collaboration is missed by DNR not fully participating in the integration process (i.e., by continuing to maintain its own dataset.) As confirmed in Options #1 and 2, while streams and open water features could be maintained within NHD, some other important DNR features (i.e., Public Waters Basins, NWI wetlands, DNR Catchments and islands) cannot. The question remains whether it is worth the effort for DNR to change its current business practices (as indicated by Options #1 & #2) to move towards a data model (i.e., NHD) that doesn't fully support all of its business needs.

References

Chapter 1c: DNR Hydrography Dataset Overview

Chapter 6: Maintenance Options

Chapter 7 (a-c): Option Testing and Results

Option 3: Resource Estimate

Option # 3: Business-focused editing and lagged synchronization to NHD

The resource estimate for Option 3 is split into two parts. The first table below shows the one-time initial set up resources and their costs. The second shows the weekly recurring costs of each of the resources required.

Task	Staff Resource Costs	Non-staff Resource Costs
Configure ArcGIS Online (AGOL) web application & editor access[1]	AGOL Administrator (8 hours)	AGOL account (pre-existing)
Create AGOL service(s) [1]	AGOL Programmer (16 hours)	
Connect AGOL and data services[1]	AGOL Administrator (8 hours) [1]	
Create notification, conflict resolution and approval workflow	AGOL Administrator (16 hours) [1]	
Create "provisional edits" geodatabase[1]	GIS Editor (8 hours) [1]	ArcGIS (pre-existing)
Customize web application[1]	AGOL Programmer (24 hours) [1]	AGOL account (pre-existing)
DNR develop summary statistics scripts[1, 2]	DNR Editor (16 hours) [1, 2]	ArcGIS/Python (pre-existing)
Totals	**AGOL Administrator (32 hours)** [1] **AGOL Programmer (40 hours)** [1] **GIS Editor (8 hours)** [1] **DNR Editor (16 hours)** [2,3]	**None (outside of what we already pay)**
	96 hours total	

Table7-3a. *Setup one-time costs*

Task	Staff Resource Costs	Non-staff Resource Costs
Maintaining AGOL site[1]	AGOL Administrator (1 hour) AGOL Programmer (1 hour)	MN.IT-maintained server
Editing MN NHD data[1]	GIS Editors (2 hours x 3 agencies) [1] DNR Editors (2 hours)	ArcGIS (pre-existing)
Pre-notification, review, conflict resolution, approval	GIS Editors (1 hour x 3 agencies) DNR Editors (1 hour)	Webx or Lync for meetings if needed (pre-existing)
Sub-Stewards update federal NHD[1]	Sub-Stewards (2 hours x **3** agencies) [1]	NHD GeoEdit Tools (no cost)
Event management	GIS Editors (2 hours x 3 agencies) DNR Editors (1 hour)	ArcGIS (pre-existing) or NHD HEM tools (free download)
DNR derived layer management	DNR Editors (1 hour)	ArcGIS/Python (pre-existing)
DNR synchronize DNR/NHD datasets [1,2]	DNR Editors (1 hour) [1,2]	ArcGIS (pre-existing)
MN Steward copies USGS copy to GDRS	MN Steward (1 hour)	ArcGIS (pre-existing)
Totals	**AGOL Administrator (1 hour)** **AGOL Programmer (1 hour)** **GIS Editors (15 hours)** **DNR Editors (6 hours)** **MN Steward (1 hour)** [1,2] **Sub-Stewards (6 hours)** [1,2]	**MN.IT-maintained server; Webex/Lync; Does not include incidental, free or already-paid-for resources (e.g. travel time, ArcGIS licenses)**
	30 hours/week; 1560 hours/year	

Table 7-3b. *Recurring costs per week*

NOTE: GIS/DNR Editor hours will vary greatly depending upon data needs and staffing

[1,2] Item represents a major difference in task or total hours compared to [1]Option 1 or [2]Option 2

Chapter 7d: Recommended Option

Objective

The objective of this chapter is to recommend a Maintenance Model Option for the future maintenance of state hydrography geospatial data. This recommendation is based upon the testing and review of three different model options as described in *Chapter 6: Maintenance Options* and *Chapter 7: Maintenance Option Testing and Results*.

Results and Conclusions

The results of testing and review of Options #1-3 by agency partners led to the following recommendation (e.g., a combination of component strategies from Options #1 and #2):

1) ***Multiple Editor Environment:*** all partners use the state NHD (from the GDRS) as the base hydrography dataset (Option 2)

2) ***DNR Referencing Strategy:*** DNR references its two core data layers (for streams and open water) as events to NHD and generates its derived products from these core layers using existing processes (Option 1)

3) ***Pre-notification:*** all partners use ArcGIS Online to pre-notify other partners of intended edits to NHD (Option 2)

4) ***Review, Conflict Detection, Approval:*** all partners use ArcGIS Online to review proposed edits, detect conflicts, and approve features (Option 2)

5) ***Updates to the USGS federal NHD:*** all partners make approved updates directly to the USGS federal NHD using *NHDGeoEdit* tools and established procedures (Option 2)

6) ***Updates to the state NHD:*** the State Administrative NHD Steward replaces the state NHD on the GDRS with a copy of the updated federal NHD (Option 2)

- An estimate of the staff and equipment resources needed for this option appear in ***Tables 7-4a, b***
- A model diagram for this option appears in ***Figure 7-1*** (end of this chapter)

Recommendation

The final recommendation is based upon a combination of strategies from the three tested model options. This is only a recommendation and must be subject to additional discussion by management personnel of the partner agencies. Any considered solution must balance the benefits against the costs (both in staff time and hardware/software resources). If future conditions change, this recommendation must be reconsidered to ensure feasibility and determine whether it still meets business needs.

Given the results of review and testing by agency partners, we recommend the following (see ***Figure 7-1***):

1) ***Multiple Editor Environment:*** all partners use the state MN NHD (from the GDRS) as the base hydrography dataset (Option 2)

   Having all partners use the same base dataset ensures that everyone is using the proper "approved" features. This is a much simpler option than using an SDE environment, which requires skilled administrative oversight and frequent reconciliation of partner versions with the default.

2) ***DNR Referencing Strategy:*** DNR references its two core data layers (for streams and open water only) as events to NHD and generates its derived products from these core layers using existing processes (Option 1)

   By referencing its core data layers for streams and open water to NHD, DNR ensures that its core features match those that all state partners are using. However, keeping its derived product data referenced as events to these core layers simplifies data management (in comparison to referencing directly to NHD). DNR can continue to use its current processes to generate derived products from the core layers without substantially changing business practices. DNR also retains more control over its event data and can manage the release of updated derived products rather than having to migrate events as soon as the NHD features change.

   DNR can take advantage of the USGS HEM Tools for referencing both stream routes and open water polygons to NHD. (An added benefit is that, unlike standard ArcGIS tools, HEM allows for the referencing of polygon events to NHD waterbody features.)

3) ***Pre-notification:*** all partners use a shared web application such as ArcGIS Online to pre-notify other partners of intended edits (Options 2 & 3)

   ArcGIS Online (AGOL) is a relatively new technology that is rapidly becoming familiar to mainstream users. Because the *review-conflict detection-approval* process is so essential to creating products that meet the business needs of all partners, an easy solution is strongly desired. In testing, AGOL proved to be an easy-to-develop, user-friendly solution for pre-notification of partner proposed edits. Mark-up tools allow partners to easily delineate areas for intended editing. Other partners can review and comment on these intended edit areas and coordinate their edits if desired.

4) ***Review, Conflict Detection, Approval:*** all partners use ArcGIS Online to review proposed edits, detect conflicts, and approve features (Option 2)

AGOL is a simple collaborative tool for reviewing partner-proposed edits. Partners are able to upload proposed features via shapefile for consideration by other partners. (Through development of a custom feature service, partners will potentially be able to upload proposed features into a "provisional edits" geodatabase.) Conflict detection is handled by a visual review of all layers made available to the AGOL service. Reviewers can add comments and mark their approval by entering their names and approval dates into the geodatabase attributes. The geodatabase serves as a long-term archive of proposed shapes and approval status.

AGOL can readily be made available to more partners and external reviewers if desired. Non-partners may be allowed to submit (i.e., upload) enhanced features for potential incorporation into NHD, thus contributing to continued improvement of the statewide NHD dataset. To the degree that all users find the features they need in the state NHD, the more comfortable they will be in relying on NHD as their base hydrography dataset.

In comparison with SDE, AGOL requires much less administrative overhead and necessary skill-level. Although SDE versioning offers a multiple-editor environment, the knowledge base required to use it is much greater than AGOL. Managing the versioning, reconciliation and post operations can be confusing and complicated; AGOL is much more user-friendly and flexible. It would be easier to expand the AGOL application and add new users without extensive training. One of the perceived benefits of SDE (i.e., the "conflict detection" functionality) was found to work only if the *same feature* is edited in multiple versions, so it doesn't override the need to track and visually review edits.

Although ArcGIS Workflow Manager may be a useful option for managing workflow, it is also somewhat complicated. While we didn't specifically test it here, it may be possible to set up Workflow Manager in the future to communicate with the AGOL web application. (DNR will be doing some internal testing to determine these possibilities.)

5) ***Updates to the USGS federal NHD:*** All partners make approved updates directly to the USGS federal NHD using *NHDGeoEdit* tools and established processes (Option 2)

For some time, major agency partners (i.e., MPCA, USGS) have expressed interest in editing <u>directly</u> to the USGS federal NHD dataset. Several key staff from these agencies have taken the necessary training to become authorized NHD editors. They would need to take additional steps to become official state "sub-Stewards". Direct editing would not only shorten the wait time for features to be incorporated into NHD, but also allow partners to have more control over specific features for their business needs. Having multiple sub-Stewards with direct-edit authorization removes the potential "bottleneck" of waiting for a single State Administrative Steward to process all edits. Having a collaborative, pre-defined review and update process makes all partners aware of the business needs of others and fosters "good will" towards the common goal of providing a single authoritative spatial hydrography dataset for Minnesota.

6) ***Updates to the MN state NHD:*** The State Administrative NHD Steward replaces the state NHD on the GDRS with a copy of the updated federal NHD (Option 2)

This is a simple operation that could potentially be automated. However, it *will* lead to an approximate 10-day lag between the dates that partner-approved edits are uploaded to the USGS federal NHD and when they appear in the state NHD on the GDRS. (We are hoping to reduce this time frame by working with USGS.) Partners will need to plan the migration of their event data around this schedule.

Discussion

During the course of option testing, we discovered that the MN NHD dataset is currently unable to accommodate all of the hydrography features necessary to meet DNR's business needs. Within DNR, the feature classes for Public Waters basins, NWI features, DNR Catchments and islands will need to be maintained separately outside of NHD (within the DNR Hydrography dataset). NHD either lacks the necessary feature types to store these features (i.e., Public Water regulatory basins; DNR Catchments, islands) or we have not researched the feasibility of adding these features to NHD (i.e., NWI wetland polygons). There are probably additional feature datasets within other agencies for which this is also true. So although not all hydrography features will be stored within NHD, they still need to be compatible with NHD and readily available to the wider GIS community that they are intended to serve.

Because NHD as a national dataset attempts to promote standardization that works across all states, adding specific new feature types to NHD is not a simple process. In fact, USGS has rejected the notion of adding island feature types into NHD because they are not true "water" features. Because DNR considers islands to be a necessary feature of a hydrography dataset for mapping and analysis purposes, DNR would need to maintain island features as a separate feature class outside of NHD.

There are additional unresolved issues involving stream centerlines along state borders and the need to extend stream flowlines into lake polygons to allow for network path tracing in NHD. In general, these limitations have work-around solutions but they are not without additional inconveniences, inefficiencies, and/or impracticalities for agency data managers. Thus, DNR must determine if it is practical to store some DNR features (i.e., streams and open water) within NHD, while maintaining other related features (i.e., Public Waters, islands) outside of NHD given the key spatial relationships between these features.

A further concern is that agencies often maintain highly sensitive data to meet statutory or business obligations. A good example is the Public Waters basin and watercourse delineations maintained by DNR for the purposes of regulatory mapping and permitting. Since these features have important legal implications, any attempts to reference them to a shared dataset such as NHD will require strict editing rules and quality control measures to ensure their accuracy. DNR is hesitant to expose this dataset to others within a shared environment. For now, at least, the DNR's Public Waters basins data will be maintained outside of NHD but managed for topological consistency with NHD. If streams are incorporated into NHD, however, the Public Waters watercourses would be affected (as they would be linear events on NHD-derived stream features). Extra vigilance will be necessary when reviewing proposed edits to NHD flowlines so that Public Waters watercourses are not adversely affected.

Given the current limitations, the goal of having a *single, authoritative spatial hydrography dataset for <u>all MN features</u>* is not fully achievable at this time. However, streams and open water features, which make up a good percentage of the features needed by most users, *could* be shared within a single state NHD dataset. Guided by a well-defined workflow, this could (perhaps) provide a good start towards the common goal.

DNR Perspective

From a technical perspective, it would be easiest for DNR to continue its current method of doing business (i.e., outlined in Option 3). DNR's enterprise Hydrography Dataset fully meets its internal business needs; DNR currently has no stated business need (reporting or otherwise) for NHD. DNR maintains sensitive statutorily-defined data that must be kept accurate; thus, DNR is hesitant to expose this data and/or the underlying features that it depends upon, to external editors. Generally, DNR's Hydrography Dataset has more up-to-date features than the state NHD dataset, so the benefits of switching to NHD is of questionable advantage to DNR at this time. (However, if the NHD and DNR datasets were fully synchronized and there was a strong commitment to keeping them synchronized and updated over time, DNR would benefit from future enhancements to NHD by the wider GIS community.)

For DNR, the efforts to synchronize DNR's data with NHD and switch to using an NHD base would use additional staff resources to change a system that (from DNR's perspective)"isn't broken". Additionally, as stated above, this effort would not truly lead to a ***single, authoritative spatial hydrography dataset for*** *MN.* Features representing Public Waters basins, DNR Catchments, NWI and islands will still need to be stored separately outside of NHD. However, because they are topologically related to base stream and open water features, they will need to be managed and edited alongside NHD if integration moves forward. There are technical "work-around" solutions that could be used to achieve this "pseudo-integration", but their practicality should be thoroughly considered.

Given these limitations, the question arises: Why would DNR want to assume the extra work for little perceived benefit? Two reasons may be offered:

1) **Statewide Interagency Collaboration**
In the interest of creating the best statewide hydrography dataset possible, DNR should want to be a participant in this collaboration. Since much of the improved hydrography data originates within DNR, DNR would be interested in how this data is represented within NHD, not only for statewide users but for DNR staff who work with other agencies that *do* have a business need for NHD. Many users outside of DNR, MPCA and USFS look to NHD to provide a comprehensive statewide hydrography model for mapping and analysis. Although DNR may have the best data now, it stands to benefit from improved features added by other partners across the state. If users know that NHD is being actively updated and maintained, they will be more inclined to use it and contribute to its improvement.

   By participating in the collaborative edit and review process, DNR is able to approve features incorporated into NHD, ensuring that they meet DNR business needs. By being involved, DNR retains a "voice" as a major participant in the process and keeps itself from becoming "isolated", especially as other statewide users continue to adopt NHD as their base dataset. Additionally, interagency collaboration is looked upon favorably by state legislators and may lead to future funding opportunities for continuing data integration. (This is a current focus of Minnesota legislative funding initiatives.)

2) **Future Hydrography Needs and Capabilities**
DNR declined to be involved in the initial Minnesota high-resolution NHD creation process (2002-2005) for the following reasons:

1) DNR had no business need for NHD
2) DNR had its own enterprise and legacy hydrography datasets
3) NHD seemed to be a complicated model that would be hard to maintain
4) There was no business plan to keep the dataset updated

It is entirely possible that future business needs of DNR could evolve to require NHD for reporting or interagency collaboration. Thus, it would be advantageous if DNR was already participating in the synchronized maintenance of the NHD dataset.

One of the reasons that DNR has not used NHD in the past is that it wasn't being updated with the features necessary to meet DNR business needs. Under full synchronization, however, the DNR Hydrography Dataset (at least for streams and open water features) *becomes* the state NHD dataset (since DNR data will be the main source of most features). Having access to water features across state borders that have consistent structure and attributes is an advantage for hydrological modeling and watershed analysis. In addition, being able to reference DNR data to NHD allows DNR staff to take advantage of the USGS analysis tools (i.e., upstream/downstream tracing; barrier pathway analysis) available for the NHD network model.

NHD data maintenance has been improved by the availability of easy-to-use *NHDGeoEdit* conflation and update tools. Tools are also available for updating and migrating events to NHD, although standard ArcGIS Linear Referencing tools can also be used.

Conclusion

The technical aspects of NHD Synchronization and Maintenance have been fully outlined and tested in this document. The NEIEN 2008 grant has provided a good opportunity to capture the fine technical details and test various potential strategies of the complex integration process. As the outcomes of this testing are not "crystal clear", neither are the decisions to be made. The next step is to move this discussion into the realm of the agency business managers who will debate the costs and benefits of adopting the recommended (or other) option for the next phase of hydrography data integration within Minnesota.

References

- **Chapter 6: Maintenance Options**
- **Chapter 7(a-c): Option Testing and Results**

Recommended Option: Resource Estimate

Partner direct edit to USGS NHD; AGOL as pre-notification and review strategy; DNR references events to two core layers derived from NHD

The resource estimate for the Recommended Option is split into two parts. The first table below shows the one-time initial set up resources and their costs. The second shows the weekly recurring costs of each of the resources required.

Task	Staff Resource Costs	Non-staff Resource Costs
Configure ArcGIS Online (AGOL) web application & editor access[1]	AGOL Administrator (8 hours)	AGOL account (pre-existing)
Create AGOL service(s) [1]	AGOL Programmer (16 hours)	
Connect AGOL and data services[1]	AGOL Administrator (8 hours)	
Create notification, conflict resolution and approval workflow	AGOL Administrator (16 hours) [1]	
Create "provisional edits" geodatabase[1]	GIS Editor (8 hours)	ArcGIS (pre-existing)
Customize web application[1]	AGOL Programmer (24 hours)	AGOL account (pre-existing)
DNR references events to NHD (core)	DNR Editor (24 hours) [2,3]	ArcGIS (pre-existing)
DNR re-creates two core layer scripts[3]	DNR Programmer (24 hours) [2,3]	ArcGIS/Python (pre-existing)
Totals	**AGOL Administrator (32 hours)** [1] **AGOL Programmer (40 hours)** **GIS Editor (8 hours)** **DNR Editor + Programmer (48 hrs)** [3]	**None (outside of what we already pay)**
	128 hours total	

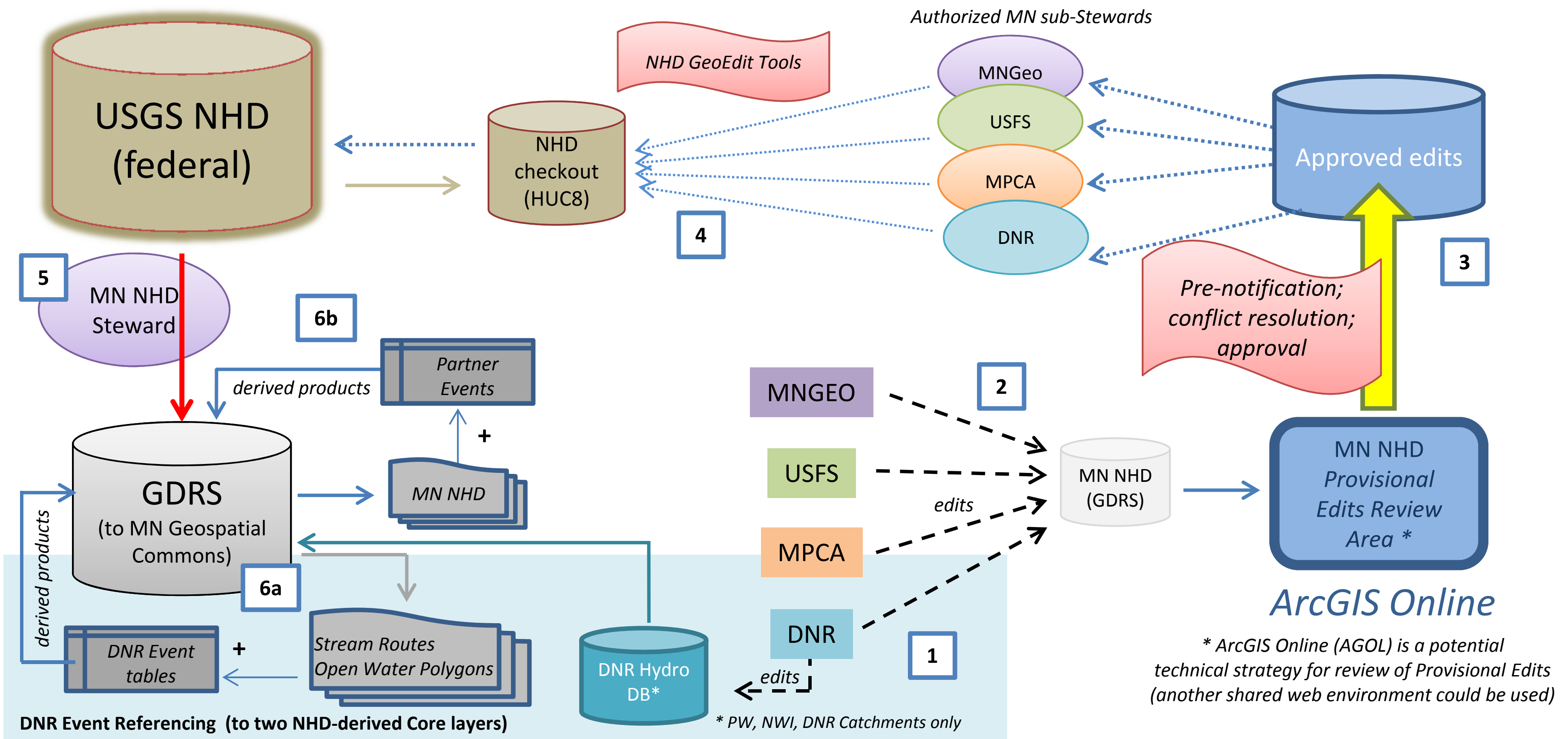
Table 7-4a. *Setup one-time costs*

Task	Staff Resource Costs	Non-staff Resource Costs
Maintaining AGOL site[1]	AGOL Administrator (1 hour) AGOL Programmer (1 hour)	MN.IT-maintained server
Editing MN NHD data (GDRS copy) [1]	GIS Editors (2 hours x 3 agencies) [1] DNR Editors (2 hours)	ArcGIS (pre-existing)
Pre-notification, review, conflict resolution, approval	GIS Editors (1 hour x 3 agencies) DNR Editors (1 hour)	Webx or Lync for meetings if needed (pre-existing)
Sub-Stewards update federal NHD[1]	Sub-Stewards (2 hours x **4** agencies) [3]	NHD GeoEdit Tools (no cost)
Event management	GIS Editors (1 hour x 3 agencies) [2,3] DNR Editors (1 hours) [2,3]	ArcGIS (pre-existing) or NHD HEM tools (free download)
DNR derived layer management	DNR Editors (2 hours) [3]	ArcGIS/Python (pre-existing)
MN Steward copies USGS copy to GDRS	MN Steward (1 hour)	ArcGIS/ (pre-existing)
Totals	**AGOL Administrator (1 hour)** **AGOL Programmer (1 hour)** **GIS Editors (12 hours)** **DNR Editors (6 hours)** **MN Steward (1 hour)** [1, 3] **Sub-Stewards (8 hours)** [1, 3]	**MN.IT-maintained server; Webex/Lync; Does not include incidental, free or already-paid-for resources (e.g. travel time, ArcGIS licenses)**
	29 hours/week; 1508 hours/year	

Table 7-4b. *Recurring costs per week*

NOTE: GIS/DNR Editor hours will vary greatly depending upon data needs and staffing
[1,3] Item represents a major difference in task or total hours compared to [1]Option 1 or [3]Option 3

Figure 7-1. Recommended Option



Highlights

1) DNR edits/maintains current Hydrography Dataset for Public Waters basins, NWI and DNR Catchments
2) All partners edit copies of GDRS NHD layers and upload proposed edits into *"provisional edits review area"**
3) A defined process guides partner *pre-notification-conflict resolution-approval* of all proposed edits
4) Authorized partner sub-stewards make approved edits to USGS federal NHD using check-out procedures & tools
5) MN Steward adds updated USGS NHD dataset to GDRS
6) (a) DNR event data is referenced to core streams /OW layers for derived products. (b) Other partner events are referenced to MN NHD (GDRS) for derived products.

Pros

- DNR is involved in the collaborative process while retaining control over its sensitive business data (Public Waters)
- AGOL is an easy-to-use collaborate tool for pre-notification and review of partner edits
- Partners have flexibility to make edits as needed without working through a single MN steward
- Most direct route for partners to get updates into federal NHD; established procedures
- Results in a single, statewide hydrography dataset (streams, OW) that meets business needs

Cons

- Does not provide ready-made QA/QC structure; a *"provisional edits area"** must be designed
- A customized *notification- conflict resolution-approval* process must be developed outside of ArcGIS
- Some features (i.e., islands) must be maintained outside of NHD but need to be spatially-aligned with NHD
- Partners need NHD training to become sub-stewards
- DNR needs to re-define current maintenance and derived product processes; increases workload
- Features from federal NHD will take time to filter back to GDRS, thus delaying event and derived layer updates

Chapter 8: Events and Event Maintenance

Objective

The purpose of this chapter is to investigate event handling as currently practiced by DNR and by the NHD User Community, and to identify ways to improve the capability to exchange and share events.

Summary

- The DNR event creation process involves using the ArcGIS Linear Referencing Toolbox to create generically-formatted events using the **Kittle_Measured_Routes** flowline dataset as the route layer. MPCA uses the NHD-sponsored Hydrography Event Management (HEM) Tool to create NHD-format events based on the NHDFlowline route layer. MPCA's NHD-format events are not stored with the national NHD database, but most are submitted to USEPA as part of Clean Water Act Reporting.

- It is possible to import an event data set created on one set of stream delineations to the other. The more closely the two stream delineations overlap, the more accurate the event transfer. Selection of a tolerance value is important. Unless the two stream delineations are coincident, some review of the data transfer results will always be necessary.

- The Department of Natural Resources tested the capability to derive most DNR streams and waterbody feature datasets as events on the NHD. That process was successful for streams and point features but not for all water body features that DNR needs to maintain. (Testing process and conclusions are described in *Appendix 8*.)

Procedural Details & Analysis

Linear Referencing and "Events"

Definitions

Linear referencing is described in the ESRI software guidance as follows: **"**Linear referencing is the method of storing geographic locations by using relative positions along a measured linear feature. Distance measures are used to locate events along the line." (*ESRI: Linear Referencing*) Linear referencing can be used to create what are known as "Events". Events are the referenced features, which in the case of hydrography can define activities, characteristics, or features in terms of their hydrologic address along a stream. Examples of point hydrographic events include stream gages, dams, and water quality monitoring stations. Examples of linear hydrographic events include stream survey reach segments, stream habitat improvement areas, trout stream designations, and stream water quality assessment areas. Usually, the event contains an identifier (e.g., stream gage number or stream survey reach segment ID) that enables a link back to tabular information about the event feature (e.g., stream flow records or stream survey results). This enables agencies to establish a hydrologic reference for their business data, and tie large volumes of sampling results to the hydrography.

This linear referencing process enables what is called “dynamic segmentation”. “Dynamic segmentation is the process of computing the map locations of events stored and managed in an event table using a linear referencing measurement system and displaying them on a map. The term dynamic segmentation is derived from the concept that line features need not be split (in other words, "segmented") each time an attribute value changes; you can "dynamically" locate the segment. Using dynamic segmentation, multiple sets of attributes can be associated with any portion of an existing linear feature independently of where it begins or ends. These attributes can be displayed, queried, edited, and analyzed without affecting the underlying linear feature's geometry.” (*ESRI: Linear Referencing*)

DNR and MPCA/USGS have taken a different approach to creating events, but the events created are transferable from one set of stream delineations to the other. The two different sets of tools used, and the events created, are described in the following sections.

Creating Events using ArcGIS Tools

The ESRI ArcGIS toolset has a set of Linear Referencing Tools in its ArcToolbox. Events can be built on any linear feature that contains routes and measures. A route is a line feature class that has a defined, consistent measurement system. Measures (m-values) can be defined in terms of a measurement unit (such as miles or meters) or a percentage (% distance up a route feature). Point events contain a single measure. Linear events contain a “from” measure and a “to” measure to define the extent of the line. Events created by the ESRI linear referencing tools are stored in tables which indicate the named route feature and measure for each event.

Events can change location if the underlying features that they are based upon change. If the line feature underneath the event is edited and changes geometry (changes spatial location, or becomes longer or shorter), the event based on that line (or lines) “floats”, or changes position based on its measure(s) in relation to the new line. In this model events are “dynamic”. They can, however, be saved out as permanent features in shape files or features classes. When events are saved out as permanent features, then over time they may no longer match the route features that they were based on.

Creating Events using Hydrography Event Management (HEM) Tool (NHD-format events)

The Hydrologic Event Management Tool (HEM) was developed by a consortium of federal agencies which are all users of NHD: USGS, EPA, BLM, and USFS. The HEM Tool builds upon the basic ArcGIS linear referencing toolset, but creates event features that assume that the NHDFlowline feature class (with “m-values” or measures) provides the Route on which to build the events, and creates the events with a pre-defined set of attributes that fit the NHD model. In addition, the events created by the HEM Tool are automatically saved to a feature class – i.e., a GIS layer. They do not “float”, as in the ArcGIS toolset, but are “fixed” as a feature class layer, based on the date of the originating NHDFlowline feature.

The purpose of this less dynamic structure is to improve the quality control in the case where the underlying features change. If the linework changes under an event, the measure(s) may then move the event to the wrong place. A casual user may not know that, and organizations may need to set up procedures to monitor events and make sure that linework changes do not corrupt them. The NHD/HEM model solves this issue by providing an “event migration” capability. In a batch process, by comparing the feature date of the underlying feature that the event was based on to the current date of the same feature, the HEM tool can identify which events need to be "migrated" onto the newer line (i.e., change position), and sets up a QA/QC process for migrated events.

Events also appear to draw more quickly when saved as feature classes – presumably because their location does not have to be calculated on the fly.

The HEM Tool also provides the capability to create an event on an NHDPoint (as long as the point has a Reach Code) or on an NHDWaterbody (containing all or part of an existing NHDWaterbody or multiple Waterbodies.) These are not "true" events in the linear referencing sense, but were needed by USGS and EPA and other organizations to help reference activities or characteristics to point or polygon features.

Agency Event Creation Activities

DNR Event Creation Process

DNR uses the standard ArcGIS Linear Referencing tools to create events. DNR has created a route feature class called "**streams_with_measured_kittle_routes"**. This feature class makes routes out of individually-recognized watercourses and has mile measures for each route. There is a single linear feature for each Kittle Number. The Kittle Number ID system for streams (i.e., Minnesota Stream Identification System) was developed by DNR Fisheries in the 1970's. (Fisheries Stream Survey Manual)

DNR creates numerous types of linear events based on the "**streams_with_measured_kittle_routes"** feature class. Data is maintained in event tables by Kittle Number and mile measures, displayed as event layers and exported to feature classes for distribution as derived stream layers (e.g., designated trout streams, Public Waters watercourses, major river centerlines, etc.)

DNR Event Creation Process Details:

- Tool: ArcGIS Linear Referencing Tools
- Route: **streams_with_measured_kittle_routes** feature class – watercourse defined by a unique kittle number is the route
- Measures : in miles (based on digitized feature, mile 0 at mouth; not official river mile markers)
- Events stored as: tables (Kittle ID, upper and lower mile measures)
- Events created: numerous (see Appendix 8)
- Maintenance Schedule: varies by product, see individual layer metadata

  DNR creates events and stores the events as tables for maintenance purposes. For general distribution, DNR exports the events out as individual feature classes and distributes to users via the GDRS.

USGS –NHD Event Creation Process

USGS uses the HEM Tool to create and maintain a set of events which it identifies as important to its mission. These include dams from the National Inventory of Dams, stream gages maintained by the USGS, National Water Information System (NWIS) water quality monitoring stations, and various categories of divergences. Over Minnesota's area of interest, USGS has created the first three event types. USGS currently creates and maintains only point events. USGS is willing to create and maintain a certain subset of event types. Other organizations are encouraged to use the tool to create local events that are based on the NHD event model.

USGS-NHD Event Creation Process Details:

- Tool: Hydrography Event Management (HEM) Tool
- Route: NHDFlowline feature class – individual feature is the route
- Measures : m-values (% of distance along route)
- Events stored as: individual feature classes for point events, line events, and area events. Different categories of events are distinguished by attribute Event_Type.
- Events created: dams, USGS stream gages, water quality stations (NWIS), divergences
- Maintenance Schedule: USGS periodically updates to reflect additional features and updated NHD linework.
- Events can also be created on points or waterbodies

NHD has an event data structure based on the NHD Hydrography layers (NHDFlowline, NHDWaterbody)

- NHDPointEventFC – point event built on NHDFlowline
- NHDLineEventFC – line event built on NHDFlowline
- NHDAreaEventFC – area event built on NHDWaterbody

  For USGS, all events fit into one of these three categories. There is an event type that describes the event (e.g., dam, stream gage, water quality monitoring station for point events).

MPCA – NHD Event Creation Process

The Minnesota Pollution Control Agency uses the HEM tool to create different types of events that it uses to support its reporting to the Environmental Protection Agency, and to record and display various attributes. Major MPCA event creation efforts support the EPA Integrated Reporting (Clean Water Act sections 305(b) Assessed Waters and 303(d) Impaired Waters); reporting to EPA on the water quality of streams, lakes, wetlands, and beaches; and indexing of MPCA's water monitoring stations to the NHD. Since these efforts are made to support reporting to EPA every two years, MPCA creates an event data set (e.g., 2012 stream assessment units), saves it out, then freezes that version until the next reporting cycle. For the next reporting cycle it will add, split, and correct reach delineations as necessary, then save/freeze that data set (e.g., 2014 stream assessment units). The MPCA Assessment Unit (AUID) events incorporate attributes such as Designated Use Classification and Outstanding Resource Value Waters. Layers and shapefiles depicting these attributes can be derived from the AUID events. Other products derived from the events are the 305(b) and 303(d) spatial data subsets, made available for reporting and public use.

MPCA Event Creation Process Details:

- Tool: Hydrography Event Management (HEM) Tool
- Route: NHDFlowline feature class – individual feature is the route; or NHDWaterbody for polygon events
- Measures : m-values (% of distance along route)
- Events stored as: Local event data sets saved out as feature classes or shapefiles. Format is originally based on the NHD point, line, and area event feature classes, but the distribution version may add or delete attributes.
- Events created: Water Quality Monitoring Assessment Units (AUIDS) for streams, wetlands, and lakes (Lake AUID number is DNR DOWLKNUM), Beach Assessments, Water Quality Monitoring Stations, and Altered Watercourse**.**

  Maintenance Schedule: AUID events are maintained continually to match MPCA water quality program needs. An official set of events used for assessments is generated biennially, to meet EPA reporting requirements. Altered Watercourse events are updated annually. Monitoring stations do not have a current maintenance plan.

Event Maintenance

Reasons for event updating

Event datasets may need to be updated when one of two things happen:

- Event features need to be added or removed from the event data set: for instance, stream gages are added or dropped, new stream habitat improvement areas are added, or two adjacent areas are merged into one.
- The underlying stream network on which the event is based has changed. A stream flowline may become more sinuous, or less sinuous, or longer or shorter, or be dropped entirely.

The ArcGIS Linear Referencing Tools and the HEM tool take two different approaches to event data storage which affects how event maintenance is managed.

Using the ArcGIS linear referencing tool the event dataset is defined as a table which stores route and measure information (although the user also has the option to save the event data set out as a separate geometry.) In this model the event can “float” as the underlying delineation changes, and the event will always align with the delineation, even after modification (unless, of course, the feature on which it is based is deleted.) However, after the underlying feature is geometrically modified, the event point or line may no longer be in the correct physical location. Based on the required update cycle, the event data owner will have to develop a process to deal with this. Events can be added or dropped as needed, and the event owner needs to develop a process to track that as appropriate: can the data set just change over time? Is it important to designate and save out annual data sets?

ArcGIS Toolbox tools that would be used to check and migrate events are described in the next section, under “DNR Event Maintenance Process”.

The HEM tool, using the route and measure information on the NHDFlowline feature class, automatically creates a feature class for the event data set. This feature class can be a point, line, or polygon feature class as defined by the user. When the underlying features are modified, then the event may no longer be in sync with the NHD feature it is referenced to. For example, overlaying the event layer on the edited NHD Flowline may show that the line or point event no longer coincides with the underlying flowline).

Unlike ArcGIS Toolbox tools, the HEM tool also allows “polygon events”, which can be referenced to waterbody features that are the same size or larger than the event. A polygon event may refer to the entire waterbody (e.g., a designated trout lake) or to only a portion of it (e.g., a bay or littoral zone of a lake). Polygon events are automatically saved as polygon feature classes.

The rationale for automatically saving HEM events as feature classes is presumably to aid in maintenance. With a large event database, USGS needed to be able to track where changing NHD Flowline geometry may have corrupted the event location. The HEM tool manages this with an Event Migration process: it enables a user to “migrate” the events from one version of NHD onto a newer version of NHD. By comparing the date of the event’s underlying NHD Flowline feature(s) on the original NHD dataset (stored as the event attribute “ReachSMDate”) and the date on the newer NHD dataset, it determines which events need to be “migrated” and not just copied. Thresholds can be set, and a QC process lets the users verify the location of migrated events and move them along the flow network if necessary. The tool also tracks changes in the underlying feature identifiers in case a feature that supported an event has had its Reach Code changed.

DNR – Event Maintenance Process

DNR has two categories of events:

1) Linear or point events that are used to create "semi-permanent" stream-derived layers involving entire or partial stream segments or locations. Once defined in event tables, they are unlikely to change much <u>unless</u> the underlying geometry changes.
    a. Examples of semi-permanent linear events include designated trout streams, Public Waters watercourses, major river centerlines, etc.
    b. Examples of semi-permanent point events include locations of dams, water control structures, culverts, stream gages, road crossings, etc.

2) Linear or point events that represent activities or "observations" collected along streams. These events are less likely to be permanent, but may track historical conditions and observations. These collections of events will continue to grow over time.
    a. Examples of "observational" linear events include electrofishing sampling stations (e.g., from mouth to mile 3), stretches of pools/rapids/runs, habitat improvement segments
    b. Examples of "observational" point events include single sampling stations (e.g., where a water sample was taken), erosion areas on banks, beaver dams, etc.

Both set of events are maintained as floating event tables upon the *Streams with Kittle Numbers and Mile Measures* feature class. In addition to Kittle Number ID and lower/upper mile attributes, original UTM XY locations are recorded for features that are defined at "fixed" locations (e.g., at road crossings or PLS Section Lines). Events that involve the entire stream route (e.g., Major River Centerlines) are marked with the attribute [ENTIRE] = "Y", indicating that the entire route should be included in the event even if the length changes.

DNR uses standard **ArcToolBox: Linear Referencing Tools** to update event table data. If the underlying stream route geometry changes, events are reviewed as to their movement along the stream. Event "errors" due to geometry changes can be found by using ***ArcMap: File: Add Data: Add Route Events*** or ***ArcToolbox: Linear Referencing Tools: Make Route Event Layer*** (note: the *Generate a field for locating errors* box must be checked under Advanced Options). "Fixed" feature locations are moved back to their original locations. If [ENTIRE] = "Y" and the stream route changes length, the event table measures are updated to match the entire length of the stream. After events are properly updated, event layers are exported as new feature classes for the GDRS.

USGS - NHD Event Maintenance Process

Using the HEM Batch event migration and QC process, USGS periodically updates events of a particular type (e.g., stream gages, dams) to reflect additional features and edited NHD delineations. This maintenance process is generally done a HUC-4 at a time.

MPCA – NHD-format Event Maintenance Process

MPCA Assessment Unit stream events are built to support multiple aspects of the water quality programs. Events are created for representation of monitoring and assessment activities, use class designations, and other attributes. Maintenance to this dataset includes continual additions of new events and modifications of event measures to conform to program needs. Every two years, this data set is locked to create the spatial data accompanying the 305(b)(Assessed Waters) and 303(d)(Impaired Waters) reports to EPA, and to create subsets of Assessed and Impaired Waters to be used in MPCA work supporting restoration and protection programs. The same process is followed for lake and wetland Assessment Units, mainly consisting of additions of newly identified wetlands and the delineations of bays. Approximately every three years, these data sets are migrated to an updated set of NHD linework and polygons.

The Altered Watercourse events are modified once a year based on input gained by fieldwork conducted by MPCA biologists. Each year this work is limited to approximately 7 HUC-8's. MPCA will migrate this data set to new NHD linework during the event update.

MPCA has created station events for biological monitoring, surface water discharge, and lake and stream water quality monitoring. These events have not been migrated to newer NHD linework. MPCA hopes to develop a maintenance plan for station events in the future.

Referencing Events across Datasets

Overview

As part of an investigation of event maintenance best practices, the project team reviewed processes for moving events created on one set of stream flowline delineations to another. MnGeo tested the process of referencing DNR-created events to the NHDFlowline, as well as the process of referencing MPCA-created, NHD-format events to the DNR **streams_with_measured_kittle_routes** feature class. In addition, as a means of verifying data maintenance options 1 and 2, DNR performed in-depth testing of the process of creating DNR streams-derived data sets as events on NHD. Given the complexity of the DNR testing, results of that test are described in a separate appendix (*Appendix 8*).

Test of referencing DNR events to the NHD dataset (Creating NHD-format events from DNR Events using the HEM tool).

DNR stores event data sets as tables in their main hydrography SDE database, but exports them out as feature classes for distribution via the GDRS. Once ported to NHD, these events are described as "NHD-format" events here because they are local events based on the NHDFlowline route and measures and stored in a standard NHD event data structure – but these events will not be sent to the national NHD database.

To move DNR events onto the NHD one would import the DNR event features from the exported distribution feature classes rather than from the event tables per se. The more coincident the underlying DNR (kittle routes) and NHD (NHDFlowline) stream geometries are, the more successful the conversion (and the less time needed for quality control.) It is possible that exported statewide event files will need to be partitioned into sections. Most event creation or migration using the HEM tools has been done a HUC-4 or a HUC-8 at a time.

The process:

- Copy DNR exported event feature class (from GDRS)
- Convert to geographic (unproject) to match NHDFlowline projection.
- To set up new event feature class:
  - In ArcCatalog, using HEM Toolbar:
    - Click **Event Feature Class Manager** button
    - Using **Event Feature Class Manager Tools: Add New**: This sets up a new event feature class and specifies event name, event type (point, line, polygon), and event spatial reference, set up event creation – names event, defines event type (point, line, polygon), and creates empty NHD event shell that the DNR exported events will be imported into.
- To create events:
  - In ArcMap, using HEM Toolbar:
    - **ArcMap: Start Editing:** Identify event feature class to be edited (i.e., the event feature class created in ArcCatalog HEM session)
    - Using **HEM Tool, Edit Tools>Import to Events.**
    - In **Import To Events** Dialog Box: specify Feature Class to import (DNR event dataset); Link Field (ID field to be kept from import dataset); and QC Database, then click **Import**. Draft events are written to the QC Database.
    - Using **HEM Tool, Edit Tools>Import to Event QA/QC**: Performs QC Process on draft events in scratch space (steps through events based on spatial thresholds).
    - Edit events as necessary to move onto the NHDFlowline
    - Approve events, apply to main events table.
    - Current DNR events would be lines or points. This process can also work for DNR polygons, too, as long as there is an NHDWaterbody polygon that overlaps and is equal in size or larger than the input DNR polygon.

Test of referencing NHD-format Events to DNR Hydrography (DNR Kittle Measured Routes delineations) Routes

Events created in NHD can be transferred to the DNR Kittle Measured Routes flowline layer, as follows:

- Copy NHD Event feature class (e.g., MPCA 2012 Stream Assessment Units) **env_assessed_streams_2012** from MPCA GDRS to local workspace.
- Make sure projection matches that of DNR **streams_with_measured_kittle_routes** (should be UTM Zone 15 NAD 83).
- Use **ArcGIS Linear Referencing Toolkit**:
  - **Locate Features Along Routes:** This creates a table with route ID and measure(s), from the DNR Routes layer, and appends the attribute information from the input data set.

    - Dataset can be saved out as a feature dataset. (Drawing the events works more quickly once data are saved out. Otherwise event extents need to be created on the fly every time they are redrawn.)
- Alternatively, the **ArcGIS Linear Referencing Toolbox**: "**Transform Route Events" tool** can be used. From the ESRI documentation: The **"Transform_Route_Events"** tool enables a process that:
    - "transforms the measures of events from one route reference to another and writes them to a new event table."
        - "Transforming events allows you to use the events from one route reference with another route reference having different route identifiers and/or measures."
        - "Any whole or partial event that intersects a target route is written to the new event table."
        - "The best results will be achieved when the source routes and the target routes closely overlay."
        - "Using a large cluster tolerance to overcome discrepancies between the source and target routes can produce unexpected results." (ESRI: Transform Route Events)

General Comments on both processes

- The closer to coincident that the two sets of stream lines are, the more accurately the events will transfer from one set of lines to the other.
- Setting of tolerances is important. Setting a tolerance value greater than zero is important to be able to capture the events at all – even projection changes the geographic reference slightly, and setting a tolerance of "0" would mean having to review every line transferred. Setting the tolerance too high would result in more error in the results, as the incorrect lines could be selected.
- Some review of the migrated data will always be necessary.

Creating DNR streams derived data sets as Events on NHD

DNR did additional testing of processes to create DNR streams layers as derived data layers referenced to the NHD. Appendix 8 (DNR Event Referencing Strategies) describes this testing. Major results of that testing (from the Appendix) are as follows:

- Two essential DNR core base layers (representing streams and open water features) <u>can</u> be successfully derived from NHD datasets. This option allows DNR to continue using existing processes to create derived products without significant changes in operation.

- DNR's core <u>and</u> derived product layers (representing streams and open water features) <u>can</u> be successfully derived from events referenced directly to the NHD dataset. This option requires that DNR develop new processes for generating derived products directly from NHD.

- *Hydrologic Points of Interest (HPOI)* <u>can</u> be maintained as point events on the DNR streams core feature class (Options 1 & 3) and directly referenced to NHD flowlines.

- Under all options, DNR retains control of its event data (i.e., it is not stored directly in NHD).

- DNR Hydrography core feature classes representing Public Waters Basins, National Wetlands Inventory and DNR Catchments cannot be derived from any NHD feature class and will need to be maintained separately by DNR.

References

Appendix 8: DNR Event Referencing Strategies
-outlines DNR testing of referencing data to NHD as events and generating DNR derived products

ESRI ArcGIS 10.1 Help – "What is Linear Referencing?" (ESRI: Linear Referencing)

ESRI ArcGIS 10.1 Help – "Transfer Route Events (Linear Referencing)" (ESRI: Transfer Route Events)

Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Fisheries ***Fisheries Stream Survey Manual, Stream Survey Methods***, Special Publication No. 165, Version 2.1. St. Paul, MN, May 1, 2007 http://files.dnr.state.mn.us/publications/fisheries/special_reports/165.pdf (Fisheries Stream Survey Manual)

Chapter 9 : Watershed (Hydrologic Unit) Mapping: Background and Organizational Business Needs

Objective

The purpose of this chapter is to provide an overview and history of watershed (hydrologic unit) mapping in Minnesota, describe the major federal and state mapping activities and outline the business needs that these mapping activities are intended to support.

Results & Conclusions

- Federal watershed mapping responsibilities resulted in a set of nested "hydrologic units" known inclusively as the Watershed Boundary Dataset (WBD).
- These hydrologic units represent drainage areas for states and across state and national boundaries.
- WBD HUC-8 represents the "container" for the NHD hydrography features. (WBD HUC-8 is the same level as Minnesota's "DNR Major Watersheds").
- The Minnesota DNR has been legally charged with mapping a consistent set of hydrologic boundaries for the state.
  - The first effort was the 1979 Watershed Mapping Project, which created the 81 DNR Major Watersheds and 5,600+ DNR Minor Watersheds.
  - The 1998 Lake Watershed Delineation Project was tasked to delineate watersheds for all lakes in the state with a surface area of 100 acres or larger, as well as to update the DNR Major Watersheds and DNR Minor Watersheds from the 1979 Watershed Mapping Project.
- The "DNR Catchments" dataset is the smallest delineated hydrologic unit and is used to create the lake watershed boundaries and the DNR Major and Minor Watershed datasets.
- It is recognized that, even though state organizations need watershed delineations at a fine level of detail (DNR Catchments), these state delineations should nest within the larger federal delineations, so that they could be used as the local building blocks and feed improvements to the delineations to the federal database.
- The DNR Catchments dataset has been used to generate the published version of the WBD. As updates are made to the Catchments in the future, the two data collections need to remain synchronized.
- As these datasets are widely distributed and used for a variety of purposes, it is very important that organizations are consistent in naming and documenting the data and eliminating duplication and confusion about data pedigree and intended use.

Procedural Details & Analysis

Watershed Mapping in Minnesota

It is common worldwide to use the terms “drainage area”, “catchment”, “watershed” and “basin” and “hydrologic unit” interchangeably. The word “watershed” has become ambiguous, representing many meanings across different disciplines. There may be better terminology. However, it is often more practical, habitual, and widely accepted to use the word watershed in text and conversation (Vaughn, S.R., p. 82). The glossary to this document has entries for “watershed”, as well as the more specific drainage area terminology used by DNR and WBD.

Federal watershed mapping: Water Resources Council, USGS, NRCS

Hydrologic Units (USGS, NRCS): In the 1970’s the United States Geological Survey (USGS) and the Water Resources Council created a mapping and classification system that divides and subdivides the United States into successively smaller river basin drainage units. These levels of subdivision, used for collection and organization of water resources data, are called “Hydrologic Units”. The units represent natural and altered stream-drainage areas. As noted in the “definitions” section, not all of these can be “classic” watersheds. The Natural Resources Conservation Service (NRCS) had further subdivided the mapping units during the 1980’s. Later NRCS, working with other federal and state agencies and the Federal Geographic Data Committee, worked to create a new watershed mapping standard at the federal level. The first draft of that standard was submitted for review in late 2002. This standard expanded the national system of delineation and numbering into six levels of hydrologic units. This expanded delineation system is referred to as the national **Watershed Boundary Dataset**. *(WBD History)*

The **Watershed Boundary Dataset** (WBD) is one of the National Framework Geographic layers, established under the auspices of the Subcommittee on Spatial Water Data and the Federal Geographic Data Committee (FGDC). As described on the WBD website, “The Watershed Boundary Dataset (WBD) defines the areal extent of surface water drainage to a point, accounting for all land and surface areas. Watershed Boundaries are determined solely upon science-based hydrologic principles, not favoring any administrative boundaries or special projects, nor particular program or agency. The intent of defining Hydrologic Units (HU) for the Watershed Boundary Dataset is to establish a base-line drainage boundary framework, accounting for all land and surface areas.” *(WBD Home)* WBD data is distributed by the United States Geological Survey as part of the NHD Dataset, and by the Natural Resources Conservation Service (NRCS) via its Geospatial Data Gateway. The NHD data distribution options include HUC-8, HUC-4, or state (http://nhd.usgs.gov).

The WBD consists of a set of nested hydrologic units delineated and named according to the WBD standard. *(WBD Delineation Standards)* The hydrologic units are nested, from smallest to largest, as follows: HUC-12 → HUC-10 → HUC-8 → HUC-6 → HUC-4 → HUC-2.

The HUC-12 is the smallest hydrologic unit delineated nationwide. Some areas (but none in Minnesota) have been further delineated to a HUC-14 and HUC-16 level. The HUC-2 is the largest hydrologic unit delineated. Minnesota is part of four HUC-2 units: Great Lakes (04), Upper Mississippi River (07), Souris-Red-Rainy River (09) and Missouri River (10). In Minnesota the DNR Catchments fulfill the need for smaller hydrologic unit representation. The DNR Catchments are a hydrologic unit, but they can be any size that meets the DNR delineation criteria, and are not part of the nested federal HUC system.

HUC-8 boundaries had always formed the "container" for the NHD hydrography (streams and lakes) features, but those boundaries had been derived from a less-detailed (1:500,000-scale) basemap. In 2012 the WBD became the hydrologic unit framework for the NHD Hydrography features and was officially incorporated into NHD. The WBD replaced the former "Hydrologic Units" feature dataset in the NHD and the Hydrography features were "migrated" to match. This "migration" meant that, within a WBD HUC-8 all NHD features had, as part of their reach codes, the correct 8-digit HUC code from WBD.

State Watershed Mapping Activity (Minnesota Department of Natural Resources)

The Minnesota Department of Natural Resources (DNR) is the legally recognized watershed mapping agency for the State of Minnesota. A summary of state watershed mapping history is provided in this document. A more complete history is maintained by DNR Staff (Vaughn, S.R.)

Minnesota Statutes define watersheds in terms of the "State of Minnesota Watershed Boundaries – 1979 Mapping Project." This project by the Department of Natural Resources represented a major effort to develop an official, systematic, detailed height-of-land boundary map for all watersheds of the state. The Watershed Mapping Project identified and delineated what became known as the 81 DNR Major Watersheds and approximately 5600 DNR Minor Watersheds.[i] *(DNR History)* The "Major Watershed" boundaries were based on the USGS 8-digit hydrologic unit delineations available at the time, but delineated at a more detailed scale. Boundary adjustments were made over the years, but the basic watershed concept and numbering scheme remained the same.

In 1998 the Legislature authorized DNR to begin a statewide re-mapping of watersheds. DNR was charged with delineating the contributing watersheds of all lakes over 100 acres in size, as well as revising the existing DNR Major and Minor Watershed boundaries as necessary. The base watershed delineation dataset developed for this "modern" watershed dataset is called DNR Catchments and is the foundation from which all other data layers within the DNR Watershed Suite are now derived. The complete set of DNR Catchments was published in 2010. New DNR Major Watershed and DNR Minor Watershed datasets were derived from the DNR Catchments dataset. *(Vaughn, S.R.)*

As of July 2010, the data originally based on the 1979 Mapping authorization were designated as "Legacy" watersheds and the data based on the 1998 authorization were designated the "Modern" watersheds. For this modern dataset, the data resources available to facilitate the creation of the delineations were superior to the information previously available. The basic naming and numbering schemes for the data, as well as the level of delineation for the DNR Major and Minor Watersheds that agencies are familiar with, have not changed.

The state's basic hydrologic unit building block, the **DNR Catchments** (officially entitled, "**DNR Watersheds – DNR Level 08 – All Catchments"**), is described in the DNR Data Catalog and will be downloadable from the Minnesota Geospatial Commons *(Metadata)*. The following description of the DNR Catchments Dataset and derived products is from ***DNR Watershed Project: History, Methodology, Terminology & Data Attribution,*** (*2014) (Vaughn, S.R., pp. 28-29):*

“The DNR-WDP *(Watershed Delineation Project –ed.)* defines a DNR Catchment as the smallest manually delineated and digitized drainage area mapped by the Minnesota DNR Watershed Delineation Project (DNR-WDP) that contains all land area(s), as well as noncontributing inclusions and water features, upstream from, or between Hydrologic Points of Interest (HPOI) defining other DNR Catchments. There is no size limit as to how small the delineation may be. Catchments are scale-independent hydrologic unit delineations, delineated to capture surface water for an area of interest. An individual DNR Catchment in the dataset may represent the drainage area of a 1-acre prairie wetland or a 100-acre recreational lake. Being the smallest delineated component of the dataset, these new DNR Catchment delineations coupled with GIS tools are more applicable to projects from small to large scales since there are more subdivisions of watersheds than with the DNR Minor and DNR Major Watersheds.”

DNR Catchment Derived Products

“The DNR Catchment delineations are developed to create a base dataset from which other statewide Minnesota DNR watershed datasets are derived. Behind the scenes, the Minnesota DNR Catchment SDE dataset is the maintenance version for all watershed and hydrologic unit delineations in Minnesota.”

“Essentially, DNR Catchments define the elementary drainage “building blocks” used to define watersheds and hydrologic units of varying sizes; they (DNR Catchments) aggregate upwards within a DNR hierarchical classification system to define hydrologic units of larger sizes.”

“In particular, DNR Catchments share coincident boundaries that aggregate together to define DNR Basin Watersheds, DNR Minor Watersheds and DNR Major Watersheds, respectively. DNR Catchments can also be combined to define DNR Level 01 (HUC 02) through DNR Level 06 (HUC 12) watersheds.”

“These units also correspond to hydrologic unit delineations defined nationally by the United States Geological Survey and the Natural Resources Conservation Service within the Watershed Boundary Dataset. This nested hierarchical system is simplified by the use of Levels as illustrated in Table 5” *(from Vaughn, S.R. document, reproduced here as Table 9-1).*

Relationships Between WBD and DNR Watershed Mapping Units

Table 9-1. *DNR HU Levels vs. Federal HUCs (Vaughn, S.R., p. 109)*

DNR Hydrologic Units Compared To Federal HUCs								
DNR HU Level	**Availability**	**Former USGS HUC Name**	**Current NRCS/USGS HUC Name**	**Federal HU Digit**	**Minnesota DNR Equivalent Name/Dataset**	**Size**	**Number of Units (Nation)**	**Number of Units (Minnesota)**
1 (Equivilent)	WBD	Regional	Region	2	n/a	Average: 178,000 sq. miles	21	4
2 (Equivilent)	WBD	Subregional	Sub-region	4	n/a	Average: 16,800 sq. miles	222	~ 30
3 (Equivilent)	WBD	Accounting	Basin	6	n/a	Average: 10,600 sq. miles	352	~ 35
4	**DNR GDRS/Deli**	Cataloging	Sub-basin	8	DNR **Major** Watersheds	Average : 703 sq. miles (450,000 acres)	2,149	81
5 (Equivilent)	WBD	-	Watershed	10	n/a	63 - 391 sq. miles (40,000 - 250,000 acres)	22,000 (estimate)	-
6 (Equivilent)	WBD	-	Sub-watershed	12	n/a	16 - 63 sq. miles (10,000 - 40,000 acres)	160,000 (estimate)	-
7	**DNR GDRS/Deli**	n/a	n/a	n/a	DNR **Minor** Watersheds	> 3,000 acres	-	5,600
8	**DNR GDRS/Deli**	n/a	n/a	n/a	DNR **Catchments**	2 acres to ~ 200,000 acres	-	~ 10,300 and increasing
9	**DNR GDRS/Deli**	n/a	n/a	n/a	DNR **Auto** Catchments	0.2 acres to ~ 2,000 acres	-	~ 148,000

A few comments on this table:

The DNR Level 4 = WBD HUC-8 is also distributed as part of WBD. DNR distributes the DNR Major Watersheds as part of its "DNR Watershed Suite" of data. The DNR Major and Minor Watershed datasets are cut off at the state border, because that is the dataset referenced in Minnesota Statutes. In some parts of the U.S., WBD has been further subdivided into levels HUC-14 and HUC-16. Minnesota has not been subdivided **within WBD**. The DNR Catchments provide the smaller hydrologic units for the state. While it is tempting to identify the DNR Minor Watersheds and DNR Catchments with WBD HUC-14 and WBD HUC-16, respectively, is not a correct use of the data as it exists currently. The DNR Catchments, as the basic building blocks of the DNR watersheds, can be any size and therefore do not fit into the WBD structure.

Past Integration of the DNR Catchments and WBD Datasets

As illustrated in Table 9-1, there are built-in relationships between the DNR and WBD watersheds. There have been two efforts to synchronize the DNR Catchments delineations with the WBD Hydrologic Units. Both involved staff from DNR Waters and USGS Minnesota. These efforts are described in *Chapter 10*, which outlines processing steps used in past synchronization efforts and recommended steps for future activity. The second synchronization activity, which was funded as part of this project, resulted in a new WBD HUC-series (HUC-2 to HUC-12) that was entirely derived from the DNR Catchments layer published by the WBD in August 2011.

Watershed-Related Business Needs

Watershed-Related Business Needs Supported by the Watershed Boundary Dataset

USGS and NRCS, in their **Stewardship of the Watershed Boundary Dataset (WBD) Factsheet**, cite the following business needs supported by the WBD:

"The Watershed Boundary Dataset complements the NHD and supports numerous programmatic missions and activities including:

- watershed management, rehabilitation and enhancement
- aquatic species conservation strategies
- flood plain management and flood prevention
- water-quality initiatives and programs
- dam safety programs
- fire assessment and management
- resource inventory and assessment
- water data analysis
- water census" *(WBD Stewardship)*

Since the WBD hydrologic unit delineations cross state (and now national) borders, these delineations have become the default drainage area delineations for studies of similar multi-state hydrologic units. Since the WBD was officially integrated into the NHD as the "hydrologic units" basis for the NHD, a new business need is to maintain and update the WBD boundaries in a manner consistent with the NHD hydrography. Since the HUC-8 boundaries form the "containers" which define Reach Code values for the Hydrography, this raises the need for the NHD and WBD to remain integrated, with updates coordinated between the two datasets.

Watershed-Related Business Needs of the Minnesota Department of Natural Resources

DNR was mandated to create the Minnesota's watershed dataset and uses these delineations to support a range of activities. Specifically, the DNR was mandated to define watershed boundaries for all Minnesota lakes with a surface area of 100 acres or larger. The mandate also included verifying and updating existing statewide major and minor watershed delineations using GIS technology (Web: DNR Mapping Watersheds). The U.S. Environmental Protection Agency has defined a "Watershed Approach" for assessing and improving water quality around the county. Because DNR and MPCA are tasked with extensive water management responsibilities relating to water quantity and water quality, respectively, these two agencies are primary state drivers of the watershed approach. DNR's legislative mandate to delineate a consistent set of watershed boundaries for the state provides the geographic framework for the watershed approach.

The 1998 legislative mandate to delineate contributing watersheds of all lakes over 100 acres in size recognizes that, in order to assess and improve lake functions and water quality, it is necessary to identify the entire upstream contributing drainage area to a lake. Once able to delineate the total upstream area, it is possible to quantify land activities and characteristics that affect water quantity and quality in lakes from upstream sources.

There is no published GIS layer of the contributing areas to all lakes over 100 acres. Such a layer would involve large numbers of overlapping polygons (probably identified by the DNR Lake ID, DOWLKNUM). However, DNR has developed and freely distributes the DNR Hydrography Toolbar – Upstream/Downstream Tool Watershed, which identifies all upstream (or downstream) DNR Catchments for any selected DNR Catchment. These aggregations of upstream catchments can be saved out as a geometric representation from any given outflow point of a delineated DNR Catchment and can be used to generate all contributing DNR Catchments to a lake by starting with the DNR Catchment which defines a lake's outflow point.

DNR has administrative divisions covering Ecological and Water Resources, Fisheries and Wildlife, Parks and Trails, Lands and Minerals, and Forestry. All of these DNR Divisions have needs for an accurate watershed layer. DNR also recognizes a responsibility to provide these delineations to the broader community beyond state agencies. Like the previous DNR watershed mapping activities, the Lake Watershed Delineation Project is intended to support hydrologic studies by local planners, watershed managers, consultants, biologists, lake associations and other agencies and organizations. *(DNR Mapping Watersheds)*

Watershed-Related Business Needs of the Minnesota Pollution Control Agency

The Minnesota Pollution Control Agency has defined a watershed approach as its strategy for water protection:

"The MPCA employs a watershed approach to restoring and protecting Minnesota's rivers, lakes, wetlands. During the 10-year cycle, the MPCA and its partner organizations work on each of the state's 81 major watersheds to evaluate water conditions, establish priorities and goals for improvement, and take actions designed to restore or protect water quality. When a watershed's 10-year cycle is completed, a new cycle begins."

"The primary feature of the watershed approach is that it focuses on the watershed's condition as the starting point for water quality assessment, planning, implementation and measurement of results. This approach may be modified to meet local conditions, based on factors such as watershed size, landscape diversity and geographic complexity (e.g., Twin Cities metro area)." *(MPCA Watershed Approach)*

"For each lake and river/stream found to have "impaired" water quality, the MPCA determines the steps needed to restore the water to meet applicable standards. For waterbodies now meeting their standards, protective measures are defined to ensure that water quality remains good." *(MPCA Watershed Data Integration)* Part of the analysis of impaired lakes and streams is fully understanding the characteristics of the total upstream contributing area for management purposes.

Because of its EPA reporting requirements, MPCA needs to use the WBD boundaries as stored within the NHD dataset as its base for reporting. For the watershed assessment cycle, the MPCA now uses the WBD HUC-8 delineations as the cataloging units. Since the WBD HUC-8 and the DNR Major

Watersheds define essentially the same boundaries, and since there are so many MPCA documents and products that reference projects by DNR Major Watershed name, MPCA still uses the DNR Major Watershed names on maps using WBD HUC-8 polygons, rather than the WBD HUC-8 names.

For watershed studies of smaller areas, MPCA historically used the legacy NRCS HUC-11 watershed unit for watershed studies. The NRCS HUC-11 (or Conservation Needs Inventory Watersheds) – was a subdivision of the HUC-8 that formed a hydrologic unit larger than the DNR Minor Watersheds within the DNR Major Watersheds, and at one time was determined to be an appropriate size for the watershed studies at the MPCA. Today the NRCS HUC-11 (Conservation Needs Inventory) as a subdivision of the HUC-8 is no longer maintained, having been replaced by the HUC-10 and HUC-12 (WBD).

MPCA is in the process of moving away from the HUC-11 dataset as a reporting unit for their business needs. As an example, for their watershed approach, a sampling framework has been developed that relies on a set of aggregated HUC-12 polygons. In many cases, the HUC-10's are slightly too large to meet MPCA's needs. Developing appropriate aggregations based on the HUC-12's to suit the need for the MPCA sampling framework is a time-intensive project.

For site-specific studies that do not fit into the standard reporting and sampling areas described above, the contributing drainage area needs to be determined. In these cases, especially where much smaller drainage units are required, MPCA uses the DNR Catchments as a building block to help define them.

Watershed-Related Business Needs of the U.S. Forest Service

Minnesota's national forests (i.e., Chippewa National Forest and Superior National Forest) are part of the U.S. Forest Service's Eastern Region (Region 9). It is the policy established by U.S. Forest Service Region 9 that NHD is the authoritative hydrography layer and WBD is the authoritative watersheds layer for the Region. Other regions have adopted NHD and WBD, but there is no clear national USFS policy. National reporting requirements on watershed activities and projects, however, do assume the use of WBD for identification and area purposes. Minnesota's national forests use the WBD to report and monitor watershed conditions, and as the basis for watershed analysis. Watershed Condition Classifications for the national forests, as required by the USFS Watershed Condition Framework (http://www.fs.fed.us/publications/watershed/), are based on WBD HUC-12's. When Chippewa National Forest staff needs smaller watershed and hydrologic unit delineations for project-specific analysis, they use the DNR Minor Watersheds and DNR Catchments.

Maintenance of Watershed Data

Stewardship of the Watershed Boundary Dataset

As WBD was incorporated into the NHD framework, more attention was paid to the need to keep the layer updated and maintained in a consistent manner across the U.S. A WBD Stewardship process was initiated, similar to that for the NHD Hydrography. "Stewardship is defined as the formalized accountability for the management of data resources. In January of 2012, national responsibility for stewardship and maintenance of the Watershed Boundary Dataset transferred from NRCS to the USGS.

Incorporation of the WBD as a companion dataset into the National Hydrography Dataset (NHD) was the driver behind integrating these two highly dependent datasets into one program." *(WBD Stewardship)*

"Collaborative stewardship of WBD data is distributed across the Nation, typically on a State-by-State basis. The WBD In-State Stewards coordinate and assume responsibility for identifying and implementing changes at the State level. Other organizations with specific local or topical interests may assume further stewardship under the auspices of the WBD In-State Stewards. In many cases, the State data stewards for the NHD and WBD are represented by different individuals and organizations." *(WBD Stewardship)*

The stewardship process assures that updates to the WBD are done as part of a federal-state partnership. Submitted updates are consistent with the published standards, specified update tools (or approved equivalent) are used to maintain the integrity of the data model, and updates are approved by the WBD National Technical Coordinators for inclusion into the national WBD. The national technical team for WBD works closely with state stewards to review proposed edits and assure that all work is done consistently with federal delineation standards.

In some states, the stewardship of NHD hydrography features and WBD hydrologic unit features is undertaken by the same organization. In states where NHD and WBD stewardship are performed by different organizations, there needs to be close coordination between the two stewardship organizations to assure that edits to one dataset are consistent with the other. Since the WBD Hydrologic Units (especially the HUC-8) serve as "containers" for the NHD hydrography features, it is important that both sides are aware of the implications of their edits for the other dataset. While there is no signed WBD stewardship agreement in Minnesota at this writing, DNR Waters and USGS-Minnesota are informally recognized as the sources for information on updates to WBD.

Maintenance of the DNR Catchments Database

The Minnesota Department of Natural Resources has the legislative authority to maintain the DNR Catchments dataset in Minnesota. Past update activities to the DNR Catchments have been sporadic in nature, initiated mainly by requests from DNR state hydrology staff based on field work observations.

In 2013, a statewide LiDAR data collection for Minnesota was completed. In anticipation of having a completed statewide LiDAR dataset, DNR has declared a moratorium on new Catchments edits. [ii] DNR has decided that the LiDAR data and or its derived products could become the basis for a regeneration of the statewide Catchments dataset. However, this is being postponed until DNR and partners undertake a thorough study of methodologies for generating LiDAR-derived watersheds and recommend best practices.

At this time the expectation is that, once a best practices methodology for DNR Catchments has been recommended and resources are made available for a wholesale, LiDAR-based updating of the DNR Catchments dataset, updates will be en masse rather than a piecemeal updating of features.

State Needs: The Need for Consistency in Terminology, Use and Citation of Watershed Boundaries

Most organizations in the state use either the DNR Watershed Suite or the WBD Hydrologic Units for mapping and reporting. **It is important that the two datasets remain aligned**. At the higher level of detail the DNR provides the only consistently mapped data statewide. For the larger reporting units (i.e., HUC-2, HUC-4, or HUC-8), it is important that users get the same delineation whether they are using the DNR or the WBD data. These two base datasets were aligned as part of this project, but they could diverge again. *Chapter 10* describes why the data diverges and what can be done to keep it in alignment.

It is also recognized that lake watershed boundaries, built from the basic building block the DNR Catchment, are an important set of overlapping boundaries, which can be identified by their DNR Lake Identifier (DOWLKNUM). Whether these boundaries are built on the fly using the DNR Level 08 Catchments dataset, or whether pre-built for distribution, these must contain the entire upstream drainage area that contributes to the lake, and not just the immediate lake drainage area. While these are constructed from the same base (DNR Catchments), they constitute a different dataset representing an aggregation on contributing DNR Catchments that have been dissolved to form one polygon representing the total upstream drainage area.

The Minnesota DNR is a primary distributor of watershed data to Minnesota users and is very concerned that the various datasets are understood, referenced and used appropriately. The watershed definitions, mapping processes and appropriate uses are all outlined in the document ***DNR Watershed Project: History, Methodology Terminology & Data Attribution (2014).*** *(Vaughn)*

State working guidelines for consistency include to:

- Accept DNR Catchments as the smallest –level hydrologic delineation and make sure that this dataset remains totally integrated with WBD: (Catchments→DNR Minor Watersheds→HUC-12→HUC-10→HUC-8 (DNR Major Watersheds)→HUC-6→HUC-4→HUC-2).
- Although constructed from the same base, accept that Lake Watersheds are a separate dataset entirely and are not to be confused with the above hydrologic units.
- Understand that there are always instances where a specialized reporting area is required and these are "custom" delineations. For instance, very small watersheds for particular studies must be defined by surveying or through LiDAR derivation.
- Recognize that Watershed District and Watershed Management Organization boundaries in Minnesota are legal boundaries which tend to follow administrative boundaries and are therefore not hydrologic representations of drainage areas.
- Use of proper and consistent citation of the datasets is extremely important.

References

Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD), Chapter 3 of ***Section A, Federal Standards, Book 11, Collection and Delineation of Spatial Data.*** Techniques and Methods 11-A3, Fourth Edition, 2013. United States Geological Survey and Natural Resources Conservation Service. *(Earlier versions of this document may have been in force when delineations were originally made). (WBD Delineation Standards)*

Federal Standards and Procedures for Delineation of Hydrologic Unit Boundaries; Version 2.0 (Federal Geographic Data Committee, 10/01/2004).

Mapping Watersheds in Minnesota – Why are Watersheds Important to Minnesotans? Minnesota Department of Natural Resources. (http://files.dnr.state.mn.us/publications/waters/lakeshed_mapping.pdf) *(DNR Mapping Watersheds)*

Stewardship of the Watershed Boundary Dataset (WBD) – *(USGS-NRCS Fact Sheet). http://nhd.usgs.gov/WBDstewardshipInfoSheet.pdf (WBD Stewardship)*

Vaughn, S.R. ***DNR Watershed Project: History, Methodology, Terminology & Data Attribution,*** (*2014).* Unpublished manuscript. Minnesota Department of Natural Resources – Ecological and Water Resources. *(Vaughn, S.R.)*

Metadata: ***DNR Level Watersheds – DNR Level 08 – Catchments:*** http://deli.dnr.state.mn.us/metadata/wshd_lev08py3.html *(Metadata)*

Web: ***History and Standards of Watershed Delineation in Minnesota:*** *http://www.dnr.state.mn.us/watersheds/history_standards.html Minnesota Department of Natural Resources – Ecological and Water Resources. (DNR History)*

Web: ***Watershed Boundary Dataset Website***: http://nhd.usgs.gov/wbd.html , United States Geological Survey, 2014. *(WBD Web Home)*

Web: ***Overview and History of Hydrologic Units and the Watershed Boundary Dataset (WBD)*** http://nhd.usgs.gov/wbd_history.html United States Geological Survey, 2014. *(WBD History)*

Web: ***National Hydrography Dataset Website:*** http://nhd.usgs.gov, United States Geological Survey, 2014. *(NHD Web Home)*

Web: ***GeoData Gateway:*** http://datagateway.nrcs.usda.gov/, Natural Resources Conservation Service (NRCS), 2014 *(GeoData Gateway)*

Web: ***Watershed Approach to Restoring and Protecting Water Quality:*** http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/watershed-approach/index.html Minnesota Pollution Control Agency *(MPCA Watershed Approach)*

Web: ***Watershed Data Integration Project***: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/watershed-approach/watershed-data-integration-project.html Minnesota Pollution Control Agency *(MPCA Watershed Data Integration)*

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[i] Note that, in 2012, two HUC-8's were combined into one as part of the US-Canada Hydrography Data Harmonization Project. That change in the HUC-8's has yet to be reflected in the DNR Major Watersheds. Historic documents will talk about the 81 major watersheds or HUC-8's in the state. Future documents will reference only 80 major watersheds. As of June, 2014, the WBD re-delineations have not yet been incorporated into the DNR work – but there is a commitment by DNR to do so.

[ii] Edits documenting delineation changes necessitated by the US-Canada Hydrography Integration Project (discussed in *Chapter 10*) will be applied to the DNR Catchments data when staff resources become available.

Chapter 10: Watershed (Hydrologic Unit) Updates and Integration

Objective

The purpose of this chapter is to describe the history of updating between the DNR Hydrologic Unit data and the national Hydrologic Unit mapping activity, and to describe a process for future updating between the DNR Level 08 Catchments and the Watershed Boundary Dataset (WBD).

Results & Conclusions

- There has always been recognition on the part of Minnesota agencies that smaller Hydrologic Unit mapping units delineated by state mapping activities would ideally fit into and feed national Hydrologic Unit mapping efforts.
- The DNR 1979 Watershed Mapping Project used the U.S. Geological Survey (USGS) 1:500,000-scale paper map, "Hydrologic Unit Map of Minnesota" (1974) - "Cataloging Units" level - as the starting point for defining the DNR Major Watersheds and DNR Minor Watersheds.
- The DNR 1998 Watershed Mapping effort added attributes for HUC-10 and HUC-12 federal designations to DNR Catchments to make possible the derivation of the federal HUC units from the smaller state DNR Catchments units.
- Two rounds of "DNR Catchments to WBD" integration have been completed, with the 2010-2011 effort resulting in a "Certified" WBD for Minnesota based on the February 2010 published DNR Catchments dataset.
- To support the WBD Stewardship activity, USGS has built a "WBDEdit" toolset similar to the "NHD Update" toolset for NHD Hydrography. The WBDEdit toolset is designed to support editing of small numbers of watershed lines rather than a full replacement of linework, as was done for the creation of the initial certified datasets across the nation.
- The DNR has declared a moratorium on new edits with the expectation that the next update of the DNR Catchments database will be a full replacement based on LiDAR-derived products . A research document on "Best Practices" for LiDAR-based watersheds will be produced.
- Therefore DNR's update process for DNR Catchment delineations will not involve small numbers of edits made periodically.
- Updates of WBD based on new geometry for an entire state is not currently supported in the WBD edit model. However, USGS has indicated that they would work try to with states to accommodate alternative update strategies if necessary.
- The federal US-Canada Hydrography Data Harmonization work on the WBD dataset, conducted with input from Minnesota WBD data stewards, resulted in changes to Minnesota HUC-8, -10, and -12 delineations along the border. These and a few other "reverse edits" need to be incorporated into the DNR Catchments layer.
- The US-Canada work resulted in the loss of one HUC-8 in Minnesota, decreasing the total number from 81 to 80.

Procedural Details & Analysis

Past Watershed Coordination and Integration Activities

Background

Beginning with the 1979 DNR Watershed Mapping Project, there has always been an acknowledgement at the state level that, whenever possible, improved detail at finer-level hydrologic unit delineations should fit into larger frameworks, and could be used to build the larger hydrologic units established by federal agencies.

The DNR 1979 Watershed Mapping Project used as a guideline the U.S. Geological Survey (USGS) 1:500,000-scale paper map, "Hydrologic Unit Map of Minnesota" (1974). The USGS mapping effort established the foundation for future watershed delineations in the state, with its delineation of 81 "cataloging units" covering the state.[i] DNR took the 81 generalized cataloging unit boundaries from the USGS 1:500,000 base map and delineated them onto USGS 1:24,000-scale topographic maps, using the more detailed contour information on the topographic maps, as well as all available watershed map sources, to improve the height-of-land delineations. They designated these as the "DNR Major Watersheds". Within the "DNR Major Watershed" units, DNR then delineated the 5600-plus "DNR Minor Watersheds". The "DNR Major Watershed" described the same geographic area then as what later became known in the federal system as the "subbasin", and now the "HUC-8".[ii]

In 2000, Natural Resources Conservation Service (NRCS) staff traveled to Minnesota to discuss state interest in the expansion of federal Hydrologic Unit mapping, new federal Hydrologic Unit mapping standards, and delineation of hydrologic units smaller than the HUC-8 level. This was the beginning of the federal mapping effort that became the Watershed Boundary Dataset. Another conference between the NRCS mapping activity and the Minnesota hydrography community occurred at the USGS-Minnesota office in 2003. Representatives from other states were also in attendance.

As part of those discussions, DNR began looking at their watershed delineations in relation to the federal standards. A comparison of the Iowa NRCS mapping of HUC-10's and HUC-12's with the DNR Minor Watersheds illustrated the "misalignment" of mapping along the Minnesota's border with Iowa. This was to be expected because DNR's 1979 Watershed Mapping Project was done as an independent project prior to the development of the WBD mapping standards. Comparing the delineations, DNR determined that the "DNR Minor Watersheds", the smallest statewide DNR delineation unit available at the time, was more detailed than any of the "hydrologic units" (HUC-8, HUC-10, or HUC-12) then defined by the federal standards.

DNR recognized the value of federal mapping which encompassed complete hydrologic unit mapping not constrained by state boundaries. However, state jurisdiction and data availability across state boundaries stopped Minnesota's mapping at the state's borders.

In 1998, the Minnesota Department of Natural Resources had begun a new effort to map watersheds for all lakes greater than 100 acres, and to update the existing DNR Major and Minor Watershed delineations.[iii] The Major Watersheds served as the work units for the mapping. Cognizant of the federal mapping activity through the NRCS/USGS meetings, DNR Waters staff (circa 2003-2004) exerted extra effort to link the state's mapping effort to the federal mapping across state boundaries. DNR followed portions of the federal hydrologic unit mapping standard (***Federal Standards and Procedures for Delineation of Hydrologic Unit Boundaries; v 1.0 and 2.0,*** Federal Geographic Data Committee), in particular the size, naming, and numbering guidelines, to code the new DNR Catchment delineations with corresponding HUC-8, HUC-10, and HUC-12 numbers. Due to the level of detail captured for the DNR Catchment delineations, it was felt that the smallest units being mapped at the state level should be used to generate the larger HUC mapping units. The Major Watersheds were the DNR's standard work unit, and editing borders of Major Watersheds mapped later could change the boundaries of Major Watersheds previously mapped. As a result, the adjacency rectification effort of the Majors could not happen until all of the DNR Catchments had been delineated for all of the Major Watershed work units.

2008 Catchment to WBD (USGS-Minnesota, DNR)

In 2008, the USGS-Minnesota, in cooperation with the Minnesota DNR, compiled 12-digit Watershed Boundary Data for Minnesota. Because the DNR 1998 Mapping Project updated the DNR Major Watershed boundaries while developing the DNR Catchment subdivisions, discrepancies developed between the DNR Major Watershed work units. Although the work of edge-matching these adjoining work units by DNR was in progress at the time of the federal deadline, their efforts would not be complete in time. In order to meet the federal WBD timelines, the USGS-Minnesota established a project to identify and dissolve the thousands of gap and overlap discrepancies between the DNR Major Watershed work units using manual and automated GIS techniques. The federal WBD deadline at the time was driven by EPA's need for the 12-digit dataset to support watershed-based planning and reporting.

This initiative produced a *preliminary* WBD dataset (circa March 2008) that met national WBD guidelines and allowed DNR time to resolve existing gaps and overlaps following highly precise procedures outlined in the state watershed mapping project methodology. The hope was that, once the DNR Catchments layer was complete, a revised WBD could be generated.

DNR Catchments to WBD Integration (2010-2011) (USGS-Minnesota, DNR)

In February 2010, DNR completed the DNR Catchments layer delineation (including the resolution of all gaps and overlaps to create completely seamless data) and published it to the user community via the DNR Data Deli. Once there was a completed DNR Catchments layer for the state, WBD stewards were interested in getting this data fully incorporated into WBD as a new test of a state-to-federal hydrologic unit data integration process that could be used into the future. The DNR and USGS-Minnesota with funding support from MnGeo through this project developed a process to update WBD. The USGS-Minnesota office conducted the integration work, with DNR consulting throughout the process . This work was performed by the USGS-Minnesota Science Center under a contract which included a cost-share agreement.

Objectives of this subcontract were to: **"**(1) Resolve coexisting watershed dataset issue by updating WBD in Minnesota with the February 2010 DNR Catchments, and (2) Harmonize Minnesota's WBD database structure with DNR Catchments." *(Project Proposal)*

Under the auspices of this project, a full transformation of the DNR Catchments to WBD was completed. The majority of the work was completed from July-December, 2010. Following data submission to the federal WBD Team (consisting of staff from NRCS and USGS), there was an extensive data review process which involved consultation over specific height-of-land delineations, naming, grouping and nesting of HUC's, and other issues including some state border resolutions. More editing work was performed in the first half of 2011, which resulted in the certified WBD layer available in August 2011.

This was a full state synchronization from DNR to WBD. This process was aided by the fact that the DNR Catchment-based WBD from 2008 was already in the system. The synchronization followed a set of processing steps (below) adapted by USGS from the "NRCS Checklist for WBD Production" *(Project Proposal)*.

- **Set up conflation environment between DNR Catchments and WBD:** *Dissolve DNR Catchments to 12-digit HUs, and create a spatial join between WBD and DNR Catchments. This data structure will enable database queries to identify inconsistencies between DNR Catchments and WBD. (Note that the DNR Catchments dataset had HUC-8,-10, and -12 codes already assigned by previous DNR efforts.)*

- **Check for item/domain discrepancies between DNR Catchments and WBD***: This will be done for all required WBD items and codes. (See Federal Standards and Procedures for Delineation of Hydrologic Unit Boundaries.)*

- **Check for edge match discrepancies between 12-digit DNR catchments and 12-digit WBD for bordering states, and 8 digit watershed data from Canadian provinces:** *Include newest watershed boundary updates from all bordering states (ND, SD, IA, and WI) and review Canadian harmonization status.*

- **Check attribute table to see if attribute fields meet "Federal Standards and Procedures for Delineation of Hydrologic Unit Boundaries".** *Verify that all required fields are complete and attributed verifying that the name fields follow NHD guidelines and that name changes are sent to federal and state cooperators.*
  - **Check to see if the 8-digit field has the correct HU code.**
  - **Check to see if the 10-digit field has the correct HU code.**
  - **Calculate the "Acreage" field from the "Area" field:** *Follow procedures outlined in: Federal Standards and Procedures for Delineation of Hydrologic Unit Boundaries.*
  - **Calculate the "State" field:** *2 digit postal abbreviations, comma between multiple states.*

- **Check that aggregated HUC-level subdivisions are consistent with federal mapping guidelines.**
  - **Check acreage of 5th level HUCs to see if they fall within recommended range (40,000-250,000 acres).**
  - **Check acreage of 6th level HUCs to see if they fall within recommended range (10,000-40,000 acres with none below 3,000).**
  - **See if the recommended number of watersheds and sub-watersheds (5-15) are nested within the next lower level**. *Check and list changes between original WBD watersheds/sub-watersheds and DNR Catchments and document any substantial changes.*

- **Check that basin numbering meets guidelines from "Federal Standards and Procedures for Delineation of Hydrologic Unit Boundaries".**

- **Check topology:**
    - o **Have all polygon silvers been removed? (the data from DNR should be clean but will check with geodatabase tools)** *Check for gaps and overlaps with geodatabase tools.*
    - o **Have all dangling arcs been removed?** *Check with geodatabase tools.*
    - o **Are all polygons closed?** *Check with geodatabase tools.*

- **Further attribute checking:**
    - o **Are all of the downstream codes correct?** *Verify that the downstream HU code is correct where and if populated.*
    - o **Does the HU level field have the correct attribute?** *This will be checked with a database query.*

- **Update metadata:** *This will include a reference to the Minnesota DNR's documentation of DNR Catchments mapping methodology.*

- **Check line work**: *Throughout the state of MN, stream confluence treatment may vary from other parts of the nation. This treatment is viewed as local knowledge and has been discussed in depth with instate partners. This issue will be addressed in the metadata.*

Note that any HUC codes that were changed as part of the full WBD certification process have not been reflected as updates to the DNR Catchments. That updating still needs to be completed.

Future Updates of DNR Catchments to WBD

Update Assumptions: Direction of Updates

The assumption of this project is that most updates originate at the state and are submitted to the WBD for integration through WBD stewardship. That is, when DNR changes delineations in the DNR Catchments feature class, this will trigger an update to WBD if the altered catchment also defines a border of a HUC-12 polygon. Conversely, changes to a DNR Catchment that is entirely internal to a HUC-12 (i.e., does not define part of a HUC-12 border) would not trigger changes to WBD.

There are a few situations where updates may travel in the reverse direction – from the federal WBD to the state dataset. Some changes initiated by surrounding states or Canada may affect Minnesota WBD boundaries, and that would have implications for DNR Catchments. For example, the hydrography data harmonization project with Canada has resulted in many edits to WBD that are not yet represented in the DNR Catchment dataset. It is believed that many of these “reverse edits” are a one-time activity. Once the outstanding “reverse edits” are completed, these situations should not reoccur. Updates remaining include:

- **WBD Certification:** Renumbering of HUC's based on changes made during the WBD Certification process in 2010-2011 needs to be incorporated back into the DNR Catchments.

- **US-Canada Data Harmonization:** The international effort to "harmonize" hydrography feature and watershed data across US-Canadian borders resulted in changes to the WBD in Minnesota, and those changes have implications for the DNR Catchments data. The harmonization of the hydrologic units began with USGS staff taking WBD (HUC-8) delineations and corresponding Canadian (CAN-4) watershed data, seaming them together, identifying problems with the matching up of delineations, and recommending solutions. Recommended solutions were brought to federal, state, and provincial staff for review, and a resolution was sought for all discrepancies relating to delineations, naming, or hydrologic unit aggregations. For Minnesota, DNR and USGS-Minnesota were involved in those reviews. The US-Canada data harmonization effort resulted in the elimination of one HUC-8 in Minnesota and changes to some HUC-10 and HUC-12 delineations, including some movement of boundaries and outflow points. DNR reviewed and approved those mapping decisions, but those changes now need to be incorporated into the DNR Catchments dataset. *(IJC)*

- **Hydrologic unit Delineations along the Great Lakes:** Watershed delineations along the Great Lakes were a problem for WBD since the Great Lakes themselves had hydrologic units" delineated for them (unlike the east and west coasts, where there is no "hydrologic unit" for the adjacent ocean.) With consultation and project design from Minnesota DNR a major delineation protocol was developed and implemented resulting in changes to the frontal watersheds along the Lake Superior shore and around the rest of the Great Lakes. As a result of this work WBD may contain changes not yet incorporated into the DND Catchment dataset.

- **Inter-state watershed boundary issues:** Occasionally, an adjacent state may have an issue that causes a boundary change. Those need to be resolved across the border.

In the case of the US-Canada Hydrography Data Harmonization, Lake Superior Mapping, and residual edits left over from the WBD certification process, these "reverse edits" are a one-time occurrence.

US-Canada work resulted in minor delineation changes and changes to HUC-8's, HUC-10's and HUC-12's which need to be incorporated by DNR back into the DNR Catchments dataset. It is very important that the changes are incorporated into the DNR Catchments since the HUC-8 (DNR Major Watershed) is a primary reporting unit for the state. DNR has committed to doing these edits to bring the DNR Catchments back into synchronization with the WBD, but has not yet had the resources to do so.

USGS WBD Update Process

Since the state's DNR Catchments-to-WBD synchronization was completed and WBD was incorporated into the NHD database, USGS has assumed the maintenance responsibility for WBD from NRCS. Whereas the initial creation and certification of the WBD layer was done on a statewide basis, USGS assumes that future edits to the WBD will be done on a more piecemeal basis. For instance, a state WBD steward might choose to update a single HUC-8 based on local knowledge, known corrections or a

LiDAR-based re-derivation of the boundaries. Of course, if a HUC-8 outer boundary is changed, at least one adjacent HUC-8 will also be affected.

In accordance with that assumption, USGS developed the "**WBDEdit**" tool, which stewards can use to edit WBD features. Like the NHD Update Tool for editing hydrography features, the WBDEdit Tool is associated with a checkout process that prevents multiple organizations from editing the same area at the same time. Training on the tool is provided regularly, and the ability to checkout, edit and return the data is restricted to WBD stewards. A QC process is part of the WBDEdit Tool, and further QC is done when the data is checked back in. Automated QC involves verifying that size, naming, and numbering criteria have been met. Some manual review of the edited features is also involved at check-in. This new procedure and toolset reflect a process where a small number of edits (or, at most, a single HUC-8) would be updated at any given time.

Future WBD Updating

For this project, MnGeo considered the updating of watersheds (i.e., WBD) to be a parallel situation to the updating of hydrography (i.e., NHD), with state-level data being used to feed the federal dataset. The path to updating hydrologic units is more straightforward than for hydrography, since it is clear that the DNR Catchments feature class is the *single* state-level dataset that needs to feed the national WBD, and that the DNR is the steward of watersheds at the state level.

At the time this project was authorized, the expectation was that a one-time synchronization of the DNR Catchments to WBD would be completed as part of this project. In addition, a key output of that synchronization would be a well-defined process for future synchronizations. Future updates were similarly expected to be full synchronizations (i.e., the full DNR Catchments dataset would be used to create a new full WBD according to a process that would be partially automated and partially manual.) DNR was expected to ensure that the coding for the HUC-12's and HUC-10's would be maintained when edits to DNR Catchments were made, and that automation would aggregate DNR Catchments to the HUC-12's and HUC-10's based on catchment attributes. It was thought that some validity testing (e.g., number and size of HUC-12's in a HUC-10, etc., and name consistency) could be done via automated scripts. Other adjustments would have to be manual – for instance, inter-state border checking. Once the state had converted the data into a full new WBD layer to HUC-12, it would be submitted to the NRCS for certification. NRCS does a number of validity checks, including a visual check of comparing delineations to elevation data as represented on the USGS 1:24,000 topographic maps. If the delineations differ from the topographic maps (as they sometimes do for Minnesota data), those delineations are accepted as long as the data submitter documents the fact that the new delineations are based on newer elevation data.

When the USGS released the "WBDEdit" tool, this was a different edit model than MnGeo previously assumed because it dealt with a set of edits to a HUC (or adjacent HUCs), i.e., changing individual feature boundaries rather than a wholesale replacement of data. Assuming that DNR would edit the DNR Catchments data as needed based on small numbers of corrections submitted by their GIS watershed and field hydrologists, it was easy to see an edit path to the WBD using the WBDEdit Tool.

However, DNR has since stated that their DNR Catchments data improvement cycle is more likely to involve a full state LiDAR-derived update rather than a piecemeal editing of DNR Catchments using the WBDEdit tools. That has implications for future WBD updating, as follows.

DNR Watershed Data Update Plans – and Implications for WBD Updates for Minnesota

Minnesota completed a LiDAR data collection in 2013, and organizations have been experimenting with using LiDAR to generate hydrography features from LiDAR products. Recent consultation with DNR has indicated that Minnesota DNR Catchment revisions are envisioned to be more of a blanket set of updates involving the whole state. Such an initiative is dependent on funding and future LiDAR elevation tool development. Given the data and the GIS tools now available, it is very easy to create hydrography features and watersheds from elevation data. However, the accuracy and reliability can be suspect. Many people are using these tools to create outputs that are not consistent with the outputs of others. As a result, DNR has declared a "moratorium" on their own DNR Catchment edits until a full study of LiDAR techniques is done which can prescribe "Best Practices" guidance for creating watershed data from LiDAR for incorporation into state data holdings for dissemination.

Once "Best Practices" have been defined, DNR expects to use current LiDAR data and LiDAR-derived products to create a **next generation** DNR Catchments layer. The new DNR Catchments dataset can then be used to derive a new set of WBD data. Since that will be a wholesale replacement of the data, the update process is more like the total data replacement model done initially than a line-by-line edit process as currently outlined by the WBD stewardship process. This has been discussed with USGS and, although it is not the current supported method for updates, they feel that they can work with the state to find a solution when the time comes.

References

Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD), Chapter 3 of ***Section A, Federal Standards, Book 11, Collection and Delineation of Spatial Data.*** Techniques and Methods 11-A3, Fourth Edition, 2013. United States Geological Survey and Natural Resources Conservation Service. *(This is the current version. Earlier versions of this document may have been in force when delineations were originally made – see below). (WBD Delineation Standards)*

Federal Standards and Procedures for Delineation of Hydrologic Unit Boundaries; Version 2.0-10/2004; Version 1.1- 12/2003 (Federal Geographic Data Committee, 10/01/2004). *(Procedures)*

Laitta, M. ***Canada-US Transboundary Hydrographic Data Harmonization Efforts Gain Momentum.*** International Joint Commission. October 11, 2010. http://www.ijc.org/rel/boards/watershed/Canada-US_Hydro_Harmonization_e.pdf *(IJC)*

Minnesota's Watershed Boundary Data Harmonization with Department of Natural Resources Catchments (Project Proposal from United States Geological Survey –WRD-MN to MnGeo, April 19, 2010). This Proposal was incorporated into the Joint Funding Agreement between USGS and MnGeo executed 6/17/2010. *(Project Proposal)*

Vaughn, S.R. ***DNR Watershed Project: History, Methodology, Terminology & Data Attribution,*** (*2014).* Unpublished manuscript. Minnesota Department of Natural Resources – Ecological and Water Resources. *(Vaughn)*

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[i] ***"Watershed Boundaries, 1979, Mapping Procedure Manual",*** unpublished manuscript, DNR Office of Planning, Policy and Research Section, Water Policy Planning Program. St. Paul, MN, June, 1979. The DNR 1979 Mapping Procedure Manual references the ***"1977 USGS Hydrologic Unit Map",*** but USGS lists that published map as follows: ***"U.S. Geological Survey, 1976, Hydrologic unit map-1974, State of Minnesota: U.S. Geological Survey, 1 sheet, scale 1:500,000."*** Note that over time *t*he terminology for classifying levels of hydrologic units has evolved. The USGS "Cataloging Units" became the "subbasins", which later became the WBD "HUC-8".

[ii] Although these versions of the DNR Major and Minor Watersheds were plotted on USGS 1:24,000 topographic maps, the first automation was based on coding of 40-acre cells as part of the Minnesota Land Management Information System (MLMIS) database. Only later were the original delineations scanned as a vector GIS layer.

[iii] DNR 1998 Lake Watershed Delineation Project http://www.dnr.state.mn.us/watersheds/lakeshed_project.html

Appendix 1: DNR Hydrography-related Derived GIS Products

- related to *Chapter 1c: DNR Hydrography Dataset Overview*

The following list contains GIS products derived from the **DNR Hydrography Dataset** as of 6/30/2014. If data is public and non-protected, layers are posted via DNR Quick Layers and **Minnesota Geospatial Commons**. (*Note: this list may be incomplete)*

* Denotes GIS layers derived from or aligned to an older data source but proposed to be updated using the DNR Hydrography Dataset

Core Feature Class

- **Open Water Basins (polygons)**

  GDRS

  - Aquaculture Ponds
  - Designated Infested Waters (Lakes)
  - DNR Fisheries Experimental and Special Regulations
  - DNR Hydro Mine Pit Features
  - DNR Hydrography - Muskie Lakes
  - DNR Lakes and Open Water
  - DNR Sentinel Lakes (SLICE program)
  - DNR Water Features
  - DNR Wetland Features
  - Fisheries Reclamation Events
  - Fisheries-stocked Waters (Lakes)
  - Fishing in the Neighborhood (FiN) Ponds
  - Lake APM Permit Locations - Lake History
  - Lake Basin Littoral Zone - 15 Foot Standard
  - Lake Basin Littoral Zone - Observed
  - Lake Basin Fetch and Maximum Length and Width
  - Lake Basin Morphology
  - Lake Bathymetric Aquatic Vegetation
  - Lake Bathymetric Contours
  - Lake Bathymetric DEM
  - Lake Bathymetric Outline
  - Lake Bathymetric DEM Shaded Relief
  - Lake Survey Data - CPUE (Catch per Unit Effort) by Lake
  - Lake Survey Data - Fish Species Found by Lake

- Lakes Managed using Shipstead-Newton-Nolan Guidelines
- Lakes Surveyed by DNR Fisheries
- Lakes with Aquatic Vegetation (GPS-collected)
- Lakes with Aquatic Vegetation (Point Intercept Method)
- Lakes with DNR Fisheries IBI Scores (Most Recent IBI Survey)
- Large Lakes in Minnesota
- Stream Trout Lakes
- Trout Lake Designation
- Walleye Rearing Ponds

Proposed

- Cisco Lakes
- Lake Temperature Classifications
- Lakes with Management Plans
- Treaty Lakes
- Waters Managed for Recreational Fishing

- **Public Waters Basins (polygons)**

GDRS

- DNR Designated Wildlife Lakes *(Wildlife)*
- DNR Migratory Waterfowl Feeding and Resting Areas *(Wildlife)*
- DNR Public Waters Delineations
- Midwest Glacial Lakes
- Shallow Lakes Identified by DNR Wildlife *(Wildlife)*
- Wild Rice Waters Identified by DNR Wildlife *(Wildlife)*

Proposed

- Shallow Lakes Program Priority Lakes *(Wildlife)*

- **Stream Centerlines (measured routes)**

  GDRS
  - Designated Infested Waters (Streams)
  - DNR River and Stream Confluences and (Flow Direction)
  - Fisheries-stocked Waters (Streams)
  - Public Waters Watercourses
  - Streams Managed using Shipstead-Newton-Nolan Guidelines
  - Stream Routes - Major River Centerlines
  - Stream Routes with Kittle Numbers and Mile Measures
  - Stream Routes with Strahler Stream Order
  - Stream Routes with Stream Types
  - Trout Stream Designation
  - Trout Stream Special Regulations
  - Trout Stream Winter Regulations
  - Wild and Scenic Recreational Rivers

  Proposed
  - Minnesota Water Trails *
  - Stream Morphology Indices
  - Stream Hydrology Indices
  - Stream Survey Data
  - Stream Survey Sampling Locations

- **DNR Level 08 Catchments**

  GDRS
  - DNR Watershed Suite
  - Stream Gage Watershed Areas
  - Watershed Health Assessment Scores (WHAF)
  - Watershed Strategies

  Proposed
  - Watershed Land Use Summaries

- **Hydrologic Points of Interest (HPOI)**

  On GDRS

  - DNR Catchment Pour Points

  Proposed

  - Bridge Inventory
  - Culvert Inventory
  - Fisheries Barriers
  - National Inventory of Dams (NID) *
  - Spring Locations
  - State Water Use Permits *
  - Stream and Road Intersections *
  - Stream Gauging System *
  - Water Access Locations *
  - Water Control Structures

- **National Wetlands Inventory (NWI)**

  On GDRS

  - NWI Circular 39 Classification (2009-2014)
  - NWI Cowardin Classification (2009-2014)
  - NWI Simplified Hydrogeomorphic Classification (2009-2014)
  - NWI Simplified Plant Community Classification (2009-2014)
  - National Wetlands Inventory Raster

  Proposed

  - Restorable Wetland Inventory *

Appendix 2a: 2013 MN Statutes & MN Rules related to Water Resources

- related to *Chapter 2a: DNR Business Needs*

The following list contains only the water-related statutes found in 2013 MN Statutes.

( ) Chapters, (●) Sub-Chapters, (o) General Headings, (▪) Statutes; **BOLD** items - specific to data management
Where only General Headings are listed, statutes are too numerous to list.

2013 MN Statutes (https://www.revisor.mn.gov/statutes/)

Chapter 84 (Natural Resources)

- STATE GEOGRAPHIC FEATURES
    - Changing and Giving Names to Waterbodies
- DEPARTMENT OF NATURAL RESOURCES
    - Enforcement of Threatened and Endangered Species
    - Protection of Threatened and Endangered Species
    - Aquatic Vegetation in Public Waters
    - Wild Rice Harvested in Certain Lakes/Natural Wild Rice Harvesting
    - Acquisition of Critical Natural Habitat
    - BWCA
    - Waterways and Water Access
    - Fish and Wildlife Resources Management Plan
    - Shoreland Management Grants

Chapter 97-102 (Game and Fish)

- GAME AND FISH
    - GENERAL PROVISIONS
        - Fish Consumption Advisories
        - Game and Fish Fund
        - Fishing on State Land
        - Fishing in Scientific and Natural Areas
        - Waterfowl Protected Areas
        - Public Water Reserves and Management Designation
        - Game Farms and Hatcheries
        - Hunting, Fishing, and Trespassing in Wildlife Management Areas
        - Public Water Access Sites
        - Wetlands for Wildlife

- POSSESSION AND TRANSPORTATION OF WILD ANIMALS
    - Possession and Transportation of Fish

- FISHING
  - FISHING HABITAT
  - PROPAGATION
  - FISHING METHODS
  - MINNOWS
  - NETTING AND COMMERCIAL FISHING

Chapter 103A-114B (Water)

- WATER POLICY AND INFORMATION

  - WATER POLICY
    - Regulatory Policy
    - Wetland Policy
    - Hydropower Policy
    - Groundwater Policy
    - Conservation Policy for Rainwater
    - Soil and Water Conservation Policy
    - Floodplain Management Policy
    - Scenic River Protection Policy
    - Water Law Policy
    - Watershed Management Policy

  - DETERMINATION OF WATER LAW AND POLICY

  - WATER INFORMATION
    - **Statewide Water Information System**
    - Director's Approval for Federal Water Data Agreements
    - Water Assessment and Reports

- WATER PLANNING AND PROJECT IMPLEMENTATION

  - BOARD OF WATER AND SOIL RESOURCES
    - Board of Water and Soil Resources
    - Local Water Management Accountability and Oversight

  - STATEWIDE WATER RESOURCE PLANNING
    - Coordination of Water Resource Planning
    - State Water and Related Land Resource plan

- METROPOLITAN SURFACE WATER MANAGEMENT
  - Metropolitan Water Management Program Purpose
  - Joint Powers Watershed Management Organization
  - Boundary Change of Watershed Districts
  - Watershed Management Organizations (WMO)
  - Watershed Plans
  - Local Water Management Plans
- METROPOLITAN GROUNDWATER MANAGEMENT
  - Groundwater Plans
- COMPREHENSIVE LOCAL WATER PLANNING AND MANAGEMENT
  - County Water Planning and Management
  - Wetland Functions for Determining Public Values
- LOCAL WATER RESOURCES PROTECTION AND MANAGEMENT PROGRAM
  - Water Plan Extensions
  - Local Water Resources Restoration, Protection and Management Program
  - Public Drainage
- SOUTH DAKOTA-MINNESOTA BOUNDARY WATERS COMMISSION
  - South Dakota – Minnesota Boundary Waters Commission
- LAKE IMPROVEMENT DISTRICTS
  - Lake Improvement Districts
- LAKE MINNETONKA CONSERVATION DISTRICT
- WHITE BEAR LAKE CONSERVATION DISTRICT
- STAR LAKES AND RIVERS

- SOIL AND WATER CONSERVATION DISTRICTS
- WATERSHED DISTRICTS
  - WATERSHED MANAGEMENT PLAN
    - Watershed Management Plan
  - DRAINAGE SYSTEMS AND PROJECTS
    - Drainage Improvements
  - GENERAL PROCEDURE TO ESTABLISH PROJECTS
    - Storm Water Facilities
  - CONSTRUCTION OR IMPLEMENTATION OF PROJECTS

- DRAINAGE
    - o GENERAL PROVISIONS
        - Drainage Inspectors
        - Ditch Buffer Strip Annual Reporting
        - Obstruction of Drainage System
        - **Hydrological and Drainage Information**

    - o OUTLETS FOR DRAINAGE SYSTEMS
    - o CONSTRUCTIONOF DRAINAGE PROJECT
    - o PROCEDURE TO REPAIR DRAINAGE SYSTEMS
    - o CONSOLIDATION, DIVISION AND ABANDONMENT OF DRAINAGE SYSTEMS

- PROTECTION OF WATER RESOURCES
    - O FLOODPLAIN MANAGEMENT
    - O SHORELAND DEVELOPMENT
    - O WILD AND SCENIC RIVERS ACT
    - O LOWER ST. CROIX RIVER
    - O MISSISSIPPI HEADWATERS PLANNING AND MANAGEMENT
    - O MINNESOTA RIVER BASIN JOINT POWERS BOARD
    - O PROJECT RIVERBEND
    - O SOIL EROSION
    - O REINVEST IN MINNESOTA (RIM) RESOURCES LAW
    - O WATER BANK PROGRAM
    - O WETLAND PRESERVATION AREAS
    - O CLEAN WATER PARTNERSHIP
    - O LAKE PRESERVATOIN AND PROTECTION
    - O WETLAND ESTABLISHMENT AND RESTORATION PROGRAM
    - O BEAVER DAMAGE CONTROL GRANTS

- WATERS OF THE STATE
    - O COMMISSIONER'S AUTHORITY
    - O PUBLIC WATERS DESIGNATION AND USE
        - **Public Waters Inventory**
    - O WETLANDS
    - O WORK AFFECTING PUBLIC WATERS
    - O WATER DIVERSION AND APPROPRIATION
    - O GENERAL PERMIT PROCEDURE
    - O WATER LEVEL ESTABLISHMENT AND CNTROL
    - O BIG STONE LAKE
    - O MISSISSIPPI HEADWATER LAKES
    - O DAM CONSTRUCTION AND MAINTENANCE
    - O FLOWAGE EASEMENTS
    - O WATER AERATION AND DEICING
    - O HARVEST AND CONTROL OF AQUATIC PLANS
    - O SUNKEN LOG RECOVERY
    - O STREAMS
    - O GREAT LAKES COMPACT

- GROUNDWATER PROTECTION
    - PROTECTION OF SENSITIVE AREAS
    - GROUNDWATER QUALITY MONITORING
    - EVALUATION AND COMMON DETECTION OF POLLUTION
- WELLS, BORINGS, AND UNDERGROUND USES
- RURAL WATER USER DISTRICTS

The following list contains only the water-related topics found in 2013 MN Rules.

2013 MN Rules (https://www.revisor.mn.gov/rules/?agency=158)

- Chapter 6100 Outdoor Recreation (boating, swimming, fishing)
- Chapter 6105 Wild, Scenic and Recreational Rivers
- Chapter 6110 Water Safety; Water Surface Use
- Chapter 6115 Public Water Resources
- Chapter 6116 Water Aeration Systems
- Chapter 6120 Shoreland and Floodplain Management
- Chapter 6116 Lakeshore Lease Appraisals
- Chapter 6133 Restitution Value for Fish and Wildlife
- Chapter 6134 Endangered, Threatened, Special Concern Species
- Chapter 6136 Natural Preservation
- Chapter 6140 Boundary Waters Canoe Area
- Chapter 6200 Game and Fish General Provisions
- Chapter 6216 Invasive Species
- Chapter 6218 Public Water Access
- Chapter 6252 Fishing Methods
- Chapter 6260 Commercial Fishing Operations
- Chapter 6262 Fishing Regulations and Requirements
- Chapter 6264 Designated Waters
- Chapter 6266 Boundary Waters Fishing Regulations
- Chapter 6268 Experimental Waters
- Chapter 6270 Aquatic Management Areas
- Chapter 6280 Aquatic Plants and Nuisances

Appendix 2b: DNR Programs and Functions related to Water Resources

- related to *Chapter 2a: DNR Business Needs*

The following list contains water-related DNR Programs and Functions as of 5/1/2014.
(Note: this list may be incomplete)

MN Department of Natural Resources – Programs and Functions by Division

(http://www.dnr.state.mn.us/aboutdnr/index.html)

- *Ecological and Water Resources*

  Ecological Resources
  - Contaminant Monitoring
  - Ecological Assistance
  - Ecological Classification System
  - Ecosystem Education
  - Environmental Review Program
  - Invasive Species Management
  - Lakescaping
  - Minnesota Biological Survey
  - Mussel Survey
  - Native plant communities
  - Nature Viewing
  - Natural Areas
  - Natural Heritage and Nongame Research
  - Nongame Wildlife Program
  - Prairie Protection and Restoration
  - River Restoration and In-Stream Flow Determination
  - Sensitive Lakeshore Identification
  - Shoreland Protection and Restoration
  - Spill Response/Fish Kills
  - Stream Protection and Restoration
  - Wetland Conservation
  - Woody Biomass Harvest for Habitat Restoration
  - Watershed Health Assessment Framework

Water Resources

- Climatology
- Dams and Dam Safety
- Drought Monitoring
- Floodplain Management and Flood Insurance
- Great Lakes/Lake Superior Coastal Program
- Groundwater Monitoring and Mapping
- Lake and Stream Monitoring
- Lake Level Monitoring
- Lakeshore Management Assistance
- Landowner Incentives Program
- Mississippi River Corridor Critical Area (MRCCA)
- Public Water Supply Plans
- Public Waters Inventory and Mapping
- Public Waters Work Permits
- Shoreland Management and Rules
- Stream Gaging/Stream Flow Program
- Water Appropriations/Use and Permits
- Water Conservation
- Watershed Delineation and Mapping
- Watershed Planning and Management
- Wild and Scenic Rivers Program

- *Enforcement*
  - Emergency Game and Fish Rules
  - Enforcement of MN Statutes/Rules/Law
  - Enforcement Permits
  - Game and Fish License Revocations
  - Incident/Accident Reporting
  - Regulations and Licenses
  - Safety Training
  - Shooting Ranges
  - Turn in Poachers Program

- *Fisheries and Wildlife*

  Fisheries
  - Angler Information, Resources and Training
  - Aquatic Management Area Acquisition
  - Aquatic Plant Management and Permits
  - Fisheries Management
  - Fishery Habitat improvement
  - Fish Pathology
  - Fisheries Research
  - Lake and Stream Survey
  - MinnAqua Aquatic Education
  - Sentinel Lakes Long-term Monitoring

  Wildlife

  - Hunter /Angler Recruitment and Retention
  - Hunter Information, Resources and Training
  - Farmer Wildlife Populations and Research
  - Forest Wildlife Populations and Research
  - Nongame Wildlife
  - Private Land Habitat
  - Project WILD Education
  - Roadsides for Wildlife
  - Shallow Lakes Program
  - Water Level Management for Wildlife
  - Wetland Wildlife Populations and Research
  - Wildlife Lake Designation and Management
  - WMA Restoration and Management

- *Forestry*
    - Burning Permits
    - Forest Certification
    - Forestry Education
    - Forest Health
    - Forest Legacy
    - Forest Resource Management Planning
    - Forest Stewardship Program
    - Private Forest Management and Assistance
    - Road Easement Access Rights
    - Rural Fire Department Assistance
    - Silviculture
    - State Forest Management
    - State Forest Nurseries
    - Timber Sales
    - Tree Planting and Care
    - Wildfire Information and Prevention
    - Wildland Fire Training

- *Lands and Minerals*

  Lands

    - Acquisitions
    - Appraisal Management
    - Easements
    - Land Exchange
    - Land Sales
    - Leases
    - Tax-Forfeited Land Review
    - Utility Crossing Licenses

Minerals

- Aggregate Resources Mapping
- Exploration Planning
- Geology Education and Recreation
- Metallic Minerals Lease Sale
- Mining, Mineral Processing and Water Quality Control
- Mineland Reclamation
- Minerals Data
- Silica Sand Mining
- State Minerals Leases
- Taconite mining and watershed restoration
- Underground Mine Mapping

- *Parks and Trails*
  - Recreation Grants
  - State Parks and Trails Planning
  - State Parks and Trails Studies
  - Water Access and Recreation
  - Waterways Planning and Management

- *Regional Operations*
  - Community Assistance
  - Regional Planning

Appendix 2c: DNR Public Waters Data

- related to *Chapter 2a: DNR Business Needs*

The following text was submitted on behalf of MNDNR's Division of Ecological and Water Resources (EWR) by Glenn Radde, MNiT Services @ MN Dept. of Natural Resources-EWR, 6/23/14. It provides additional background material related to the "proposed" incorporation of Public Waters (PW) data into the MN National Hydrography Dataset (NHD). (See *Chapters 1, 2* and *4* for additional information.)

Considerations for Public Waters Basin and Watercourse Data

The DNR's Division of Ecological and Water Resources (EWR) has concerns about Minnesota's statutory and regulatory circumstances that have driven the development of DNR's current digital Public Waters (PW) basin and PW watercourse data. Here is a summary of the history and sources of PW data.

Legislative Order for a Public Waters Inventory

The Minnesota Legislature directed the DNR to complete an inventory of all public waters - basins, wetlands, and watercourses (natural and altered-natural/public ditches) between 1979 through 1982. (Note that this inventory was a closed list, in that no corrections or changes were allowed.) The chief regulatory document was a Commissioner's Order for each county listing basins and wetlands by *Bulletin 25* identification numbers (i.e., DNR Lake ID or DOWLKNUM), official name, and a Public Land Survey legal description (i.e., Township, Range, Section). PW watercourses (as natural and altered-natural) are also listed by their Public Land Survey legal description.

As a result of the **1994 lawsuit brought by Trout Unlimited (TU) et al.**, against the MN Department of Natural Resources, DNR was directed to amend the PWI maps to indicate PLS Sections where trout stream features were considered as PW natural watercourses for regulatory purposes. (These sections were shaded to indicate the presence of trout features.) Subsequent Legislatures removed the Commissioner Order list as the primary regulatory document in favor of the map.

They also provided for making technical corrections on the regulatory map, for reclassifying certain PW wetlands into PW basins, and removing other PW wetlands from the program entirely (thereby transferring them to WCA jurisdiction).

Original PWI Maps

The original PWI maps were based on the best available base map at the time (i.e., MNDOT county highway maps at a scale of 1/2" to the mile. Sadly, the year chosen for this work was one of the few that lacked either any geographic projection or ones that were variable and undocumented. Variations in scale make this map series difficult to use in that representative scale more often is 1:126,720 than 1:125,000.)

Public Waters Definition

Minnesota Statute (103G.005 Subds 15 and 16) provides criteria for what constitutes a public water basin and a public waters wetland.

Subd. 15. **Public waters.**

(a) "Public waters" means:

(1) water basins assigned a shoreland management classification by the commissioner under sections 103F.201 to 103F.221;

(2) waters of the state that have been finally determined to be public waters or navigable waters by a court of competent jurisdiction;

(3) meandered lakes, excluding lakes that have been legally drained;

(4) water basins previously designated by the commissioner for management for a specific purpose such as trout lakes and game lakes pursuant to applicable laws;

(5) water basins designated as scientific and natural areas under section 84.033;

(6) water basins located within and totally surrounded by publicly owned lands;

(7) water basins where the state of Minnesota or the federal government holds title to any of the beds or shores, unless the owner declares that the water is not necessary for the purposes of the public ownership;

(8) water basins where there is a publicly owned and controlled access that is intended to provide for public access to the water basin;

(9) natural and altered watercourses with a total drainage area greater than two square miles;

(10) natural and altered watercourses designated by the commissioner as trout streams; and

(11) public waters wetlands, unless the statute expressly states otherwise.

(b) Public waters are not determined exclusively by the proprietorship of the underlying, overlying, or surrounding land or by whether it is a body or stream of water that was navigable in fact or susceptible of being used as a highway for commerce at the time this state was admitted to the union.

Subd. 15a.**Public waters wetlands.**

"Public waters wetlands" means **all types 3, 4, and 5 wetlands**, as defined in *United States Fish and Wildlife Service Circular No. 39 (1971 edition)*, not included within the definition of public waters, that are ten or more acres in size in unincorporated areas or 2-1/2 or more acres in incorporated areas.

It also provides for:

- *Minimum sizes*: i.e., ten acres for features outside of incorporated areas and 2.5 acres for those within these boundaries.
- (*Subd16*) provides for "dry" features to be considered in that they must be "capable of containing water."
- *(Subd15a)* states that PW wetlands must be of **USFWS Circular 39 Types 3, 4 and 5** *(Shaw and Fredine, 1956).*
- **PW watercourses** (natural and altered-natural) must have definable banks and beds with a minimum drainage area of two square miles.

Note: To compensate for these challenges on the MNDOT county map, heavy markers were used to delineate and label all PW features.

Creation of PW data from NWI data

A 1990's LCMR-funded project allowed Minnesota to acquire digital NWI data (polygon, line, and point features), convert mylar watershed maps of the state into digital linework, and to convert the NWI USFWS from the Cowardin classification into the older Circular 39 classification (defined in 103G.005 Subd 17b and used for PW). DNR acquired a near final clean copy of the NWI data in 1996-97 for this purpose. A crosswalk developed by the *MN Interagency Wetlands Group* (1996) was used to group NWI features for purposes of identifying PW basins. NWI basins with the following types were chosen to represent PW basins: *Circular 39 Types 3-4-5* wetlands and *Cowardin PUBF, PUBH, PUBG, and L1 features* (*Table A2c1*).

Ongoing PW edits

PW basin delineation work (including PW wetlands) has been ongoing since 1997. These data have gone through rigorous review by field staff. The goal for these PW basin and PW wetland data is to provide delineations that are good faith approximations of their OHWLs. Access to engineering records for control structures and the recent availability of LiDAR have greatly increased the accuracy of PW basin delineations. A rough estimate of professional staff time working on this is conservatively put at 40,000 hours to date. Because the PW basins been gone through statutory requirements and due process through numerous public hearings, their <u>delineations cannot be changed without official review and approval by DNR EWR hydrologists.</u>

Public Water Watercourses

During a 2006 map review with field staff, it became vital to have complete linework for PW watercourses on these maps. MNDOT Basemap watercourses proved to detailed enough to rely on as a fundamental data source. Several DNR projects corrected portions of these data, especially a 2004-08 effort funded by an EPA grant and 2014 funding from the DNR MPARS project which also allowed assignment of PW watercourse sequence number IDs and DNR Fisheries' Kittle ID numbers to all watercourses. (PW sequence IDs are used within PW permits databases.)

Changes to Public Waters Status

Under appropriate circumstances, basins and wetlands can be dropped from the program. PW altered-natural watercourses acquire protection as natural watercourses once the local ditch authority abandons them. Furthermore, complete watercourses can consist of natural and altered-natural segments, and these designations can change. Superseded channels may retain PW protections.

Names of Public Waters

Official Public Waters waterbody and watercourse names are created by DNR and submitted to the U.S. Board on Geographic Names for approval and subsequent addition to the federal USGS Geographic Names Information System (GNIS) database. These names, along with unique DNR Lakes IDs (i.e., DOWLKNUM) are stored in DNR EWR's authoritative lakes database called **DNR Lakes DB**.

There are many minor discrepancies in basin and watercourse feature names between the official MN state names assigned by DNR and the names that appear in the national GNIS database (which are applied to NHD features). To obtain uniformity would require **substantial resources at both the federal and state level**, given the current statutory processes in place governing them.

Challenges to storing PW data in a centralized, shared dataset

Some issues and the problems they present are:

(1) Dry or drained features are protected if they can hold water
- these features would need to be stored in NHD even though there is no visual water; there is no special NHD feature type for "dry or drained" basin so they would be called "Lake/Pond" or "Swamp/Marsh"

(2) New basins are being added when governmental units request identifier numbers
- DNR Lake IDs and official names must be assigned by DNR in coordination with DNR Lakes DB

(3) Without a proper OHWL study, wetland fringes around PW basins and PW wetlands make accurate delineation of the "container" difficult
- PW delineations must be made by a DNR hydrologist

(4) Potential changes in the identification/designation/adding/dropping of PW features
- PW modifications must be made by a DNR hydrologist

(5) Conflicts between GNIS and DNR PW official names
- official state PW names must be assigned by DNR; GNIS should change to match DNR, not vice versa

Conclusion

Because of the above factors and the important statutory obligations that DNR must meet in regard to Public Waters, DNR EWR would be opposed to allowing storage of Public Waters features within NHD. At this time, it doesn't appear that NHD can accommodate the OHWL delineations that make up the PW basins layer. However, even if it could, the above issues limit the feasibility and practicality of doing so.

Minnesota Statutes related to Public Waters:

103G.255 states that the DNR Commissioner shall administer (1) the use, allocation, and control of waters of the state; … and (3) the determination of the ordinary high water level of waters of the state.

103G.201 Public Waters Inventory states that the DNR Commissioner shall maintain a public waters inventory map of each county that shows the waters of this state that are designated public waters …. the commissioner shall send a notification or a copy of the maps to the auditor of each affected county.

103G.121 Subd 1 - The DNR commissioner may conduct surveys, investigations, and studies, and prepare maps of the waters of the state and topography of the state (to implement this chapter).

103G.125 Director's Authority — DNR EWR Director — Sudb 3 - Standards for forms and maps — The director may adopt rules to standardize forms and maps, sizes of maps, plats, drawings, and specifications in proceedings related to waters of the state.

Administrative Rules 6115.0160 references PW maps and PW features regarding review and issuance of permits.

103A.401 authorizes the DNR Commissioner to act on behalf of the state to establish and maintain a statewide water information system to gather, process, and distribute information on the availability, distribution, quality, and use of waters of the state.

- This last statute ensures that the PW program activities retain sufficient control over the necessary information resources in order to meet their statutory obligations.

References

Chapter 1c: DNR Hydrography Dataset

Chapter 2a: DNR Business Needs

Chapter 4: Synchronization of NHD and DNR Datasets

Lewis M. Cowardin et al., *Classification of Wetlands and Deepwater Habitats of the United States*,
U.S. Fish and Wildlife Service, Washington, D.C., 1979, p. 5

Minnesota Statutes and Rules: https://www.revisor.mn.gov/pubs/ State of Minnesota, 2013.

Shaw, S.P. and C.G. Fredine. ***Wetlands of the United States.*** U.S. Fish and Wildlife Service, Circular 39, 1956.

CONVERSION FROM COWARDIN WETLAND HABITATS TO CIRCULAR 39 WETLAND TYPES

(*MN Interagency Wetlands Group - ERB16OCT96*)

The following conversion of the COWARDIN habitat classification to Circular 39 wetland types was used [as suggested by Nick Rowse (U.S. Fish & Wildlife Service 24 January 1996) resulting from conversations with Kim Santos (St. Petersburg, FL)]. Of importance is that there is not a one to one conversion or crossover--for example, a PEMF wetland could be type 3 or type 4 wetlands and PABG and PUBG could be type 4 or type 5 wetlands. Water regimes denoted with a (1) may be reported as either types 3, 4, or 5.

Circular 39 classification *(Shaw and Fredine, 1956)*	**Cowardin classification** *(USFWS, Dowardin et al., 1979)*
Type 1	PEMA PFOA PUS
Type 2	PEMB
Type 3	PEMC AND F1 PSSH PUBA AND C
Type 4	L2ABF L2EMF1 and G1 L2US PABF and G1 PEMG and H PUBB and **PUBF**
Type 5	L1 L2ABG1 and H L2EMA, B and H L2RS L2UB PABH PUBG1 and H
Type 6	PSSA, C, F, and G PSS1, 5, and 6B
Type 7	PFO1, 5, and 6B PFOC and F
Type 8	PFO2, 4, and 7B PSS2, 3, 4, and 7B
Type 80	K - for industrial/municipal, never natural
Type 90	R - all riverine systems
Type 98	Uplands

Table A2c1. *Crosswalk of Circular 39 codes (used for PW basins) into Cowardin codes (used for NWI)*

Due to Circular 39 limitations, for riverine systems, a Type 90 was applied to all "R's" in the Cowardin system. For municipal/industrial activities, a Type 80 was assigned to all Water Regime "K" codes.

Deepwater habitats fall outside of the wetland system. For subsequent data analyses, the following codes were applied to deepwater habitats of PUBF (Type 94), PUBH (Type 95), PUBG (Type 96), and L1*** (Type 97). These habitats encompass a majority of the deepwater areas.

Appendix 3a: Differences between the NHD and DNR Datasets (Buffer Analysis Methods)

- related to *Chapter 3: Differences between the NHD and DNR Datasets*

Quantifying Differences between NHD & DNR Hydrography Data

This comparison methodology is broken into three sections: Stream Geometry, Stream Type, and Lake Comparison (both Geometry and Name). All input layers in quotes (“ “) can be found in the GDRS QuickLayers. The output geographic data for each section should be saved to its associated HUC number directory (e.g., \09020108). The statistical results (e.g., area, length, # records) should be recorded in G:\MnGeo\GIS Project Services\Projects\NEIEN_2008\Docs*NHD_DNR_Comparison_Results.xlsx*.

Stream Geometry Comparison

1. Select given HUC (e.g., 09020108) from “DNR Watershed Suite” layer in GDRS
2. Select By Location "Stream Routes with Kittle Numbers and Mile Measures" And “NHDFlowlines“ where they intersect selected HUC
3. Run **Dissolve**:
    a. Input Layer: “Stream Routes with Kittle Numbers and Mile Measures”
    b. Output Layer: dnr_dissolved.shp
    c. Dissolve Field(s): <blank>
    d. Statistics Field(s): <blank>
    e. Create Multipart Features: <unchecked>
    f. Unsplit Lines: <checked>
4. Run **Dissolve**:
    a. First click *Environments…* button then *Z Values* entry
    b. In *Output has Z values* textbox change *Same as Input* to *Disabled*
    c. Input Layer: “NHDFlowline”
    d. Output Layer: nhd_dissolved.shp
    e. Dissolve Field(s): <blank>
    f. Statistics Field(s): <blank>
    g. Create Multipart Features: <unchecked>
    h. Unsplit Lines: <checked>
5. Run **Multiple Ring Buffer**:
    a. Input Layer: dnr_dissolved.shp
    b. Output Layer: dnr_buffers.shp
    c. Add the following buffer distances: 0.1;0.5;1;2;3;4;5;10;20;50
    d. Buffer Unit: Feet
    e. Field Name: distanceFT
    f. Dissolve Option: ALL
6. Run **Multiple Ring Buffer**:
    a. Input Layer: nhd_dissolved.shp
    b. Output Layer: nhd_buffers.shp

    c. Add the following buffer distances: 0.1;0.5;1;2;3;4;5;10;20;50
    d. Buffer Unit: Feet
    e. Buffer distance field: distanceFT
    f. Dissolve Option: ALL

7. Run **Identity**:
    a. Input Layer: nhd_dissolved.shp
    b. Identity Layer: dnr_buffers.shp
    c. Output Layer: nhd_identity.shp
    d. Join Attributes: ALL
    e. Cluster Tolerance: <blank>
    f. Relationship: <unchecked>

8. Run **Identity**:
    a. Input Layer: dnr_dissolved.shp
    b. Identity Layer: nhd_buffers.shp
    c. Output Layer: dnr_identity.shp
    d. Join Attributes: ALL
    e. Cluster Tolerance: <blank>
    f. Relationship: <unchecked>

9. **Add** *length_ft* field (Double) to both Identity shapefiles
10. **Calculate Geometry** of *length_ft* in both identity shapefiles to Property: *Length*, Units: *Feet*
11. **Summarize** *distanceFT* fields in both identity files and **Sum** their *length_ft* fields to the outputs: sum_<nhd or dnr>_length.txt (Note: Text file output)
12. **Load** each text file into empty area of <HUC-8> worksheet of *NHD_DNR_Comparison_Results.xlsx* (In Excel: Data tab > Get External Data: From Text > Import > Delimited > Comma > Next > Finish)
13. **Copy and Paste** count and length data from text files into appropriate columns of *Stream Geometry Comparison* table
14. **Delete** any remaining data after cut and paste
15. **Switch** the values in *Missing or > 50* (0) columns from nhd to dnr (and vice versa) because they represent the other dataset (i.e. missing NHD flowlines are existing DNR streams NOT in NHD)

Stream Type Comparison

This section is similar to the Stream Geometry Comparison except that each matching set of stream types will be run through the process separately.

1. **Select given HUC** (e.g., 09020108) from "DNR Watershed Suite" layer in GDRS

2. **Select By Location** "DNR River and Stream Centerlines (Stream Type)" and "NHDFlowlines" where they intersect selected HUC

3. **Select from current selection** of both DNR streams and NHD Flowlines one group of matching stream types given in Table 1 below (e.g., for Group 1: NHD FType =334 AND DNR STRM_TYPE IN (61, 81)):

	NHD		DNR	
Group #	**FType**	**Description**	**STRM_TYPE**	**Description (STRM_LONG)**
1	334	Connector	61 81	Connector (Wetland) Arbitrary Flow Connector
2	336	Canal/Ditch	40 41 42	Drainage Ditch (Perennial) Drainage Ditch (Intermittent) Drainage Ditch (Undifferentiated)
3	428	Pipeline	71	Underground Storm Sewer
4	460 558	Stream/River Artificial Path (not within Waterbody)	20 21 22 62 63 80 90	Stream (Perennial) Stream (Intermittent) Stream (Unknown) Centerline (River) Connector (River) Interpreted Arc Connector Superceded [sic] Natural Channel
5	558	Artificial Path (not within NHDArea)	60	Connector (Lake)

Table A3a-1 Matched NHD & DNR Stream Types

Note: For Groups 4 & 5 **remove from current selection** where NHDFlowline has centroid within NHDWaterbody (Group 4) or NHDArea (Group 5).

4. Run **Dissolve**:
    a. Input Layer: "DNR River and Stream Centerlines (Stream Type)"
    b. Output Layer: dnr_<Group #>_dissolved.shp
    c. Dissolve Field(s): STRM_TYPE
    d. Statistics Field(s): <blank>
    e. Create Multipart Features: <unchecked>
    f. Unsplit Lines: <checked>

5. Run **Dissolve**:
    a. First click *Environments…* button then *Z Values* entry
    b. In *Output has Z values* textbox change *Same as Input* to *Disabled*
    c. Input Layer: “NHDFlowline”
    d. Output Layer: nhd_<Group #>_dissolved.shp
    e. Dissolve Field(s): FType
    f. Statistics Field(s): <blank>
    g. Create Multipart Features: <unchecked>
    h. Unsplit Lines: <checked>

6. Run **Multiple Ring Buffer**:
    a. Input Layer: dnr_<Group #>_dissolved.shp
    b. Output Layer: dnr_<Group #>_buffers.shp
    c. Add the following buffer distances: 0.1;0.5;1;2;3;4;5;10;20;50
    d. Buffer Unit: Feet
    e. Field Name: distanceFT
    f. Dissolve Option: ALL

7. Run **Multiple Ring Buffer**:
    a. Input Layer: nhd_<Group #>_dissolved.shp
    b. Output Layer: nhd_<Group #>_buffers.shp
    c. Add the following buffer distances: 0.1;0.5;1;2;3;4;5;10;20;50
    d. Buffer Unit: Feet
    e. Buffer distance field: distanceFT
    f. Dissolve Option: ALL

8. Run **Identity**:
    a. Input Layer: nhd_<Group #>_dissolved.shp
    b. Identity Layer: dnr_<Group #>_buffers.shp
    c. Output Layer: nhd_<Group #>_identity.shp
    d. Join Attributes: ALL
    e. XY Tolerance: <blank>
    f. Relationship: <unchecked>

9. Run **Identity**:
    a. Input Layer: dnr_<Group #>_dissolved.shp
    b. Identity Layer: nhd_<Group #>_buffers.shp
    c. Output Layer: dnr_<Group #>_identity.shp
    d. Join Attributes: ALL
    e. XY Tolerance: <blank>
    f. Relationship: <unchecked>

10. **Add** *length_ft* field and **Calculate Geometry** to Length, Feet to both Identity shapefiles

11. **Summarize** *distanceFT* field in both Identity files and **Sum** their *length_ft* fields to the output text files: <dnr or nhd>_<Group #>_sum.txt

12. **Repeat** steps 1-11 of this section for each Group (1-5) for each HUC-8.

13. **Load** each summary text file into empty area of <HUC-8> worksheet of *NHD_DNR_Comparison_Results.xlsx* (In Excel: Data tab > Get External Data: From Text > Import > Delimited > Comma > Next > Finish)

14. **Copy and Paste** count and length data from text files into appropriate columns of either DNR or NHD of given group in *Stream Type Comparison* table

15. **Delete** any remaining data after cut and paste

16. **Switch** the values in *Missing or > 50* (0) columns from nhd to dnr (and vice versa) because they represent the other dataset (i.e. missing NHD flowlines are existing DNR streams NOT in NHD)

Lake Comparison (both Geometry and Name)

1. **Select** given HUC (e.g., 09020108) from “DNR Watershed Suite” layer

2. **Select By Location** “DNR Water Features” (dnr_hydro_features_all) and “NHDWaterbody” layers where they intersect selected HUC

3. **Remove from selection** of “DNR Water Features” where: WB_CLASS LIKE 'Island*'

4. Run **Union** with the following input:
    a. Input Layers: “NHDWaterbody”, “DNR Water Features”
    b. Output Layer: dnr_nhd_lake_union.shp
    c. Join Attributes: ALL
    d. XY Tolerance: <blank>
    e. Gaps Allowed: <checked> (meaning gaps NOT allowed)

   Perform the following on the union output file dnr_nhd_lake_union.shp and record the results in the Excel file NHD_DNR_Comparison_Results.xlsx, Lakes worksheet:

5. **Add** *Unionacres* **field** (Double)

6. **Calculate Geometry** on *Unionacres* field: Area, Acres

7. R**ecord** number and acreage (Right-click *Unionacres* field > Statistics) of all records into last row (Total) of *Totals* section of *Lake Geometry & Name Comparison* table on given <HUC-8> worksheet of *NHD_DNR_Comparison_Results.xlsx*.

8. **Select By Attributes** all DNR lakes where: "FID_dnr_hy" <> -1

9. **Record** # selected records and Sum of *Unionacres* of selected records into first (DNR) row of *Totals* section of *Lake Geometry & Name Comparison* table.

10. **Select By Attributes** all NHD lakes where: "FID_NHDWat" <> -1

11. **Record** # selected records and Sum of *Unionacres* of selected records into second (NHD) row of *Totals* section of *Lake Geometry & Name Comparison* table.

12. **Select By Attributes** DNR and NHD lakes that overlap where: "FID_NHDWat" <> -1 AND "FID_dnr_hy" <> -1

13. **Record** # selected records and Sum of *Unionacres* of selected records into *Total* subsection of *Overlapping* section of *Lake Geometry & Name Comparison* table.

14. **Select By Attributes** the overlapping lakes that have the same name where: (POSITION("LAKE_NAME" IN "GNIS_Name") > 0 AND "LAKE_NAME" <> ' ') OR (POSITION("ALT_NAME" IN "GNIS_Name") > 0 AND "ALT_NAME" <> ' ')

15. **Record** # selected records and Sum of *Unionacres* of selected records into *With Same Name* subsection of *Overlapping* section of *Lake Geometry & Name Comparison* table.

Appendix 3b: Differences between the NHD and DNR Datasets (Buffer Analysis Results)

- related to *Chapter 3: Differences between the NHD & DNR Hydrography Datasets*
- see also *Appendix 3a: Dataset Difference Testing Methods*

HUC-8: Baptism-Brule (04010101); DNR Major: Lake Superior – North (1)

Stream Geometry Comparison

Within Buffer (ft)	DNR Streams			NHD Flowlines		
	Count	Sum_length (ft)	Percent	Count	Sum_length (ft)	Percent
0.1	1363	6161483.222	54.01%	3343	6161520.04	54.22%
0.5	911	105524.3296	0.92%	2206	105572.8299	0.93%
1.0	865	103696.9319	0.91%	2099	103744.4479	0.91%
2.0	845	162244.1882	1.42%	2037	162392.8967	1.43%
3.0	842	137028.2239	1.20%	2009	137228.3549	1.21%
4.0	828	123262.8807	1.08%	1976	123450.4217	1.09%
5.0	813	117239.8086	1.03%	1955	117430.8494	1.03%
10.0	816	525507.9701	4.61%	1943	525809.3155	4.63%
20.0	792	894816.5054	7.84%	1879	890739.84	7.84%
50.0	741	1725994.624	15.13%	1767	1659807.875	14.61%
Missing or > 50	1386	1351512.595	12.07%	589	1376536.628	11.89%
Total	**10202**	**11,408,311.28**		**21803**	**11,364,233.50**	

Stream Type Comparison

	Group 1					
	DNR			NHD		
Stream Type:	STRM_TYPE= 61, 81			FTYPE= 334		
Stream Type Description:	Connector, Arbitrary Flow Connector			Connector		
w/in Buffer (ft)	**Frequency**	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**
0.1	66	123141.6878	27.82%	119	123134.428	44.88%
0.5	41	910.9469159	0.21%	61	884.1240153	0.32%
1.0	40	873.6262868	0.20%	59	840.2049507	0.31%
2.0	39	1485.757198	0.34%	58	1411.47823	0.51%
3.0	39	1026.761917	0.23%	56	951.5600392	0.35%
4.0	38	975.0492122	0.22%	56	902.3660913	0.33%
5.0	37	1012.439187	0.23%	53	934.8243527	0.34%
10.0	37	3983.624306	0.90%	53	3591.488041	1.31%
20.0	37	6446.908948	1.46%	52	5550.544197	2.02%
50.0	38	16422.89151	3.71%	51	13024.30927	4.75%
Missing or > 50	643	286297.5158	64.69%	45	123162.6556	44.89%
Totals	1055	442577		663	274388	

Note: 04010101 had no DNR or NHD features of Group 2 or 3.

Stream Type Comparison

Group 4						Group 5					
DNR			NHD			DNR			NHD		
STRM_TYPE= 20,21,22,62,63,80,90			FTYPE= 460, 558*			STRM_TYPE= 60			FTYPE= 558**		
Stream (Perennial), Stream (Intermittent), Stream (Unknown), Centerline (River),			Stream/River, Artificial Path (*if not in NHDWaterbody)			Connector (Lake)			Artificial Path (**if not in NHDArea)		
Frequency	Sum Length (ft)	% of Total	Frequency	Sum Length (ft)	% of Total	Frequency	Sum Length (ft)	% of Total	Frequency	Sum Length (ft)	% of Total
1270	4605499.211	55.46%	2474	4605423.955	55.63%	308	1271528.839	46.38%	969	1271508.805	50.12%
874	49059.496	0.59%	1381	48718.0574	0.59%	282	18863.71331	0.69%	636	18749.90292	0.74%
849	50162.58552	0.60%	1309	49717.99582	0.60%	282	13776.03168	0.50%	618	13623.95149	0.54%
835	86627.7047	1.04%	1281	85719.99692	1.04%	281	20077.19697	0.73%	605	19767.79274	0.78%
832	79693.45444	0.96%	1261	78802.94362	0.95%	281	15987.89996	0.58%	598	15671.40495	0.62%
823	74944.99962	0.90%	1241	73982.47924	0.89%	281	12160.83695	0.44%	589	11840.62471	0.47%
815	72541.04148	0.87%	1231	71515.71606	0.86%	280	10631.52832	0.39%	584	10300.916	0.41%
823	330372.1708	3.98%	1237	324717.4473	3.92%	279	41975.51943	1.53%	582	40223.13369	1.59%
815	573285.4966	6.90%	1217	557694.4503	6.74%	280	62271.10238	2.27%	573	58166.96764	2.29%
795	1120121.31	13.49%	1186	1023897	12.37%	281	121144.4637	4.42%	551	106033.0109	4.18%
1432	1262186.748	15.20%	726	1358368.631	16.41%	1260	1153187.489	42.06%	280	970892.6543	38.27%
10163	8304494		14544	8278559		4095	2741605		6585	2536779	

Lake Geometry & Name Comparison

	Totals		Overlapping					
			Total			With Same Name		
	#	Acreage	#	Acreage	% of Total	#	Acreage	% of Total
DNR	1949	20,455,419.49						
NHD	2950	13,286,200.99						
Total	4899	33,741,620.48	956	13,254,063.32	39.28%	503	13,246,812.49	39.26%

HUC-8: Prairie-Willow (04010101); DNR Major: Mississippi River – Grand Rapids (9)

Stream Geometry Comparison

Within Buffer (ft)	DNR Streams			NHD Flowlines		
	Count	Sum_length (ft)	Percent	Count	Sum_length (ft)	Percent
0.1	1212	9314106.648	89.43%	2585	9314124.738	91.47%
0.5	528	73093.19308	0.70%	1037	73224.01267	0.72%
1.0	435	32842.09406	0.32%	847	32991.92964	0.32%
2.0	363	30073.03986	0.29%	706	30387.75343	0.30%
3.0	274	16434.25632	0.16%	531	16693.11028	0.16%
4.0	224	11689.1548	0.11%	441	11889.43752	0.12%
5.0	211	10118.99727	0.10%	409	10290.94878	0.10%
10.0	208	33447.34771	0.32%	399	34218.64797	0.34%
20.0	195	57142.93288	0.55%	382	58536.79864	0.57%
50.0	181	98341.54164	0.94%	372	102613.8065	1.01%
Missing or > 50	404	737685.4076	7.08%	189	498100.3873	4.89%
Total	**4235**	**10,414,974.61**		**7898**	**10,183,071.57**	

Stream Type Comparison

	Group 1					
	DNR			NHD		
Stream Type:	STRM_TYPE= 61, 81			FTYPE= 334		
Stream Type Description:	Connector, Arbitrary Flow Connector			Connector		
w/in Buffer (ft)	**Frequency**	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**
0.1	32	94869.77647	24.20%	57	94863.38522	38.98%
0.5	26	505.2371037	0.13%	14	479.7602902	0.20%
1.0	26	366.5176198	0.09%	14	334.6856103	0.14%
2.0	25	211.2134419	0.05%	11	147.6017909	0.06%
3.0	25	86.0057538	0.02%	9	23.05765263	0.01%
4.0	25	71.80601354	0.02%	8	7.640761373	0.00%
5.0	25	72.18111484	0.02%	7	7.371806222	0.00%
10.0	25	359.7671722	0.09%	7	36.86087958	0.02%
20.0	25	719.4626518	0.18%	7	73.87171549	0.03%
50.0	25	2518.512695	0.64%	8	521.3685295	0.21%
Missing or > 50	290	292286.9853	74.55%	27	146880.4179	60.35%
Totals	549	392067		169	243376	

Stream Type Comparison

Group 2						Group 3				
DNR			NHD			DNR			NHD	
STRM_TYPE= 40,41,42			FTYPE= 336			STRM_TYPE= 71			FTYPE= 428	
Drainage Ditch (Perennial), Drainage Ditch (Intermittent), Drainage Ditch			Canal/Ditch			Underground Storm Sewer			Pipeline	
Frequency	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**
204	1516495.422	83.75%	298	1516498.944	83.18%			0.00%	NO DATA	NO DATA
84	23932.85142	1.32%	102	23903.03601	1.31%			0.00%		
74	9785.745267	0.54%	81	9767.511862	0.54%			0.00%		
67	8495.308259	0.47%	67	8466.238365	0.46%			0.00%		
59	4749.901301	0.26%	51	4712.210528	0.26%			0.00%		
57	2520.321565	0.14%	42	2470.771406	0.14%			0.00%		
56	2473.161296	0.14%	40	2424.610172	0.13%			0.00%		
55	6590.308819	0.36%	39	6376.205083	0.35%			0.00%		
50	16602.71802	0.92%	34	16060.39819	0.88%			0.00%		
49	28596.66944	1.58%	33	26727.19138	1.47%			0.00%		
50	190567.8888	10.52%	63	205759.2769	11.29%	2	1255.453404	100.00%		
805	1810810		850	1823166		2	1255		0	0

Stream Type Comparison

Group 4						Group 5					
DNR			NHD			DNR			NHD		
STRM_TYPE= 20,21,22,62,63,80,90			FTYPE= 460, 558*			STRM_TYPE= 60			FTYPE= 558**		
Stream (Perennial), Stream (Intermittent), Stream (Unknown),			Stream/River, Artificial Path (*if not in NHDWaterbody)			Connector (Lake)			Artificial Path (**if not in NHDArea)		
Frequency	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**
851	5884244.558	89.30%	1803	5884186.127	85.91%	102	567078.7963	33.97%	318	567070.2182	49.70%
481	27594.73111	0.42%	669	27335.70831	0.40%	91	2678.783287	0.16%	178	2640.655098	0.23%
441	12064.24286	0.18%	518	11699.16371	0.17%	91	1730.593037	0.10%	171	1683.59688	0.15%
409	10892.13925	0.17%	400	10209.13055	0.15%	91	2209.13442	0.13%	167	2111.2959	0.19%
371	5513.88902	0.08%	273	4806.657563	0.07%	91	1928.034603	0.12%	161	1832.087279	0.16%
350	3739.494179	0.06%	206	2997.278661	0.04%	91	1727.42017	0.10%	161	1631.643338	0.14%
338	2319.066319	0.04%	178	1533.921343	0.02%	91	1712.692608	0.10%	161	1617.750459	0.14%
337	8800.217334	0.13%	169	4815.903779	0.07%	91	8283.750329	0.50%	163	7804.81986	0.68%
336	15329.20613	0.23%	161	7316.7376	0.11%	91	13925.00194	0.83%	162	12941.53898	1.13%
334	37279.07166	0.57%	157	13508.62708	0.20%	91	34629.96563	2.07%	160	31295.13007	2.74%
339	581318.2086	8.82%	368	881062.0133	12.86%	739	1033599.868	61.91%	95	510267.9749	44.73%
4587	6589095		4902	6849471		1660	1669504		1897	1140897	

Lake Geometry & Name Comparison

	Totals		Overlapping					
			Total			With Same Name		
	#	**Acreage**	**#**	**Acreage**	**% of Total**	**#**	**Acreage**	**% of Total**
DNR	1980	92,307.85						
NHD	3327	85,763.36						
Total	5307	178,071.20	1019	77,687.30	43.63%	390	57,544.78	32.32%

HUC-8: Lower-Minnesota (07020012); DNR Major: Lower Minnesota River (33)

Stream Geometry Comparison

Within Buffer (ft)	DNR Streams			NHD Flowlines		
	Count	Sum_length (ft)	Percent	Count	Sum_length (ft)	Percent
0.1	1686	12099462.76	90.00%	3111	12099443.53	92.79%
0.5	571	48342.20764	0.36%	976	48334.59113	0.37%
1.0	473	26259.79081	0.20%	796	26234.74394	0.20%
2.0	403	31411.85562	0.23%	667	31385.76946	0.24%
3.0	344	18682.72109	0.14%	571	18666.94019	0.14%
4.0	301	11069.78371	0.08%	510	11021.0999	0.08%
5.0	290	9793.803239	0.07%	486	9710.25253	0.07%
10.0	288	42039.57176	0.31%	478	41243.2996	0.32%
20.0	280	74853.71588	0.56%	454	72262.5915	0.55%
50.0	281	146628.7316	1.09%	431	132147.9708	1.01%
Missing or > 50	728	935220.2975	6.96%	296	549088.1657	4.21%
Total	**5645**	**13,443,765.24**		**8776**	**13,039,538.95**	

Stream Type Comparison

	Group 1					
	DNR			NHD		
Stream Type:	STRM_TYPE= 61, 81			FTYPE= 334		
Stream Type Description:	Connector, Arbitrary Flow Connector			Connector		
w/in Buffer (ft)	**Frequency**	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**
0.1	25	26468.90337	11.93%	29	26466.59001	30.86%
0.5	14	10.52780476	0.00%	1	0.926024198	0.00%
1.0	14	13.12955233	0.01%	1	1.157215689	0.00%
2.0	14	26.32365255	0.01%	1	2.315233462	0.00%
3.0	14	26.31201819	0.01%	1	2.314036693	0.00%
4.0	14	26.11711923	0.01%	1	2.31446558	0.00%
5.0	14	26.25048116	0.01%	1	2.315386622	0.00%
10.0	14	131.2569877	0.06%	1	11.57296795	0.01%
20.0	14	263.1504937	0.12%	1	23.14738366	0.03%
50.0	14	772.4061722	0.35%	1	73.49202472	0.09%
Missing or > 50	267	194128.4512	87.49%	19	59189.30458	69.00%
Totals	418	221893		57	85775	

Stream Type Comparison

Group 2						Group 3			
DNR			NHD			DNR		NHD	
STRM_TYPE= 40,41,42			FTYPE= 336			STRM_TYPE= 71		FTYPE= 428	
Drainage Ditch (Perennial), Drainage Ditch (Intermittent), Drainage Ditch			Canal/Ditch			Underground Storm Sewer		Pipeline	
Frequency	Sum Length (ft)	% of Total	Frequency	Sum Length (ft)	% of Total	Frequency	Sum Length (ft)	Frequency	Sum Length
668	4017874.176	90.64%	963	4017865.014	90.41%			NO DATA	NO DATA
209	20498.51922	0.46%	268	20484.64127	0.46%				
179	13040.05639	0.29%	226	13018.91339	0.29%				
152	18017.40327	0.41%	192	17980.34049	0.40%				
132	10242.32533	0.23%	170	10217.02436	0.23%				
118	4712.896231	0.11%	151	4680.068024	0.11%				
117	3591.844129	0.08%	145	3548.394539	0.08%				
115	14758.97266	0.33%	142	14573.5269	0.33%				
115	31056.1627	0.70%	141	30582.28969	0.69%				
113	51987.02273	1.17%	142	50382.51809	1.13%				
134	246995.4922	5.57%	144	260871.0403	5.87%	271	493332.0081		
2052	4432775		2684	4444204		271	493332	0	0

Stream Type Comparison

Group 4						Group 5					
DNR			NHD			DNR			NHD		
STRM_TYPE= 20,21,22,62,63,80,90			FTYPE= 460, 558*			STRM_TYPE= 60			FTYPE= 558**		
Stream (Perennial), Stream (Intermittent), Stream (Unknown),			Stream/River, Artificial Path (*if not in NHDWaterbody)			Connector (Lake)			Artificial Path (**if not in NHDArea)		
Frequency	Sum Length (ft)	% of Total	Frequency	Sum Length (ft)	% of Total	Frequency	Sum Length (ft)	% of Total	Frequency	Sum Length (ft)	% of Total
1102	7208097.46	95.52%	1775	7208036.985	89.82%	57	256711.9851	33.49%	194	256708.9512	55.15%
498	21522.88688	0.29%	450	21289.31836	0.27%	54	1584.810271	0.21%	103	1573.300097	0.34%
440	10202.8742	0.14%	322	9905.641914	0.12%	54	962.0956625	0.13%	100	947.6499959	0.20%
400	9047.995614	0.12%	246	8479.142523	0.11%	54	1148.513592	0.15%	95	1117.223939	0.24%
355	4584.940197	0.06%	167	4013.207267	0.05%	54	752.2695752	0.10%	95	717.9143137	0.15%
337	2671.339135	0.04%	133	2114.129811	0.03%	54	630.7039678	0.08%	92	596.5793067	0.13%
328	2380.537393	0.03%	115	1784.832168	0.02%	54	609.500497	0.08%	92	574.3297164	0.12%
327	10968.3129	0.15%	110	7912.021667	0.10%	54	2565.306571	0.33%	92	2383.99143	0.51%
324	17740.56605	0.24%	98	11526.44235	0.14%	54	4281.700064	0.56%	91	3883.142222	0.83%
324	32809.48418	0.43%	92	14955.14186	0.19%	56	7850.654795	1.02%	91	6885.079552	1.48%
164	226098.3362	3.00%	351	735186.913	9.16%	561	489338.3164	63.85%	59	190055.7727	40.83%
4599	7546125		3859	8025204		1106	766436		1104	465444	

Lake Geometry & Name Comparison

	Totals		Overlapping					
			Total			With Same Name		
	#	Acreage	#	Acreage	% of Total	#	Acreage	% of Total
DNR	2201	62,919.92						
NHD	4004	40,165.36						
Total	6205	103,085.28	992	32,123.53	31.16%	62	8,845.30	8.58%

HUC-8: Eastern Wild Rice (09020108); DNR Major: Wild Rice River (60)

Stream Geometry Comparison

	DNR Streams			NHD Flowlines		
Within Buffer (ft)	**Count**	**Sum_length (ft)**	**Percent**	**Count**	**Sum_length (ft)**	**Percent**
0.1	1629	10829774.31	95.03%	2509	10829792.16	94.40%
0.5	771	65155.1759	0.57%	1139	65268.73632	0.57%
1.0	549	32151.61325	0.28%	819	32333.34628	0.28%
2.0	384	27911.32179	0.24%	601	28283.94939	0.25%
3.0	262	10053.82136	0.09%	420	10362.26145	0.09%
4.0	191	7919.22807	0.07%	323	8056.227344	0.07%
5.0	168	6147.493353	0.05%	278	6253.767576	0.05%
10.0	162	25395.99858	0.22%	270	25760.13676	0.22%
20.0	156	38330.56011	0.34%	262	39197.08498	0.34%
50.0	143	54852.47547	0.48%	248	56748.10499	0.49%
Missing or > 50	230	298672.7278	2.62%	142	370060.0475	3.23%
Total	**4645**	**11,396,364.72**		**7011**	**11,472,115.83**	

Stream Type Comparison

	Group 1					
	DNR			**NHD**		
Stream Type:	STRM_TYPE= 61, 81			FTYPE= 334		
Stream Type Description:	Connector, Arbitrary Flow Connector			Connector		
w/in Buffer (ft)	**Frequency**	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**
0.1	35	82451.93416	21.99%	80	82447.64538	36.68%
0.5	29	158.6341061	0.04%	35	141.0997213	0.06%
1.0	29	141.7758905	0.04%	35	119.4991666	0.05%
2.0	29	121.9461109	0.03%	33	78.09786976	0.03%
3.0	29	117.9141076	0.03%	33	74.69316665	0.03%
4.0	29	78.98299114	0.02%	32	35.61297436	0.02%
5.0	29	79.41723169	0.02%	32	35.75124846	0.02%
10.0	29	397.1048304	0.11%	32	179.0443034	0.08%
20.0	29	794.2214126	0.21%	32	363.9558819	0.16%
50.0	29	2376.4424	0.63%	34	1144.167932	0.51%
Missing or > 50	391	288314.4256	76.88%	31	140133.0999	62.35%
Totals	687	375033		409	224753	

Stream Type Comparison

Group 2						Group 3			
DNR			NHD			DNR		NHD	
STRM_TYPE= 40,41,42			FTYPE= 336			STRM_TYPE= 71		FTYPE= 428	
Drainage Ditch (Perennial), Drainage Ditch (Intermittent), Drainage Ditch			Canal/Ditch			Underground Storm Sewer		Pipeline	
Frequency	Sum Length (ft)	% of Total	Frequency	Sum Length (ft)	% of Total	Frequency	Sum Length (ft)	Frequency	Sum Length (ft)
477	3289409.188	92.00%	622	3289398.244	87.61%	NO DATA	NO DATA	NO DATA	NO DATA
213	19995.47844	0.56%	183	19949.32189	0.53%				
192	15162.33355	0.42%	144	15100.87688	0.40%				
178	15372.22396	0.43%	116	15254.8821	0.41%				
161	5170.598875	0.14%	88	5000.905692	0.13%				
156	5367.606248	0.15%	81	5174.94475	0.14%				
154	4674.217843	0.13%	76	4528.344297	0.12%				
153	19155.90916	0.54%	76	18277.03052	0.49%				
152	27662.62518	0.77%	76	26076.47093	0.69%				
150	35277.96469	0.99%	74	29985.22527	0.80%				
78	138177.3073	3.86%	151	325990.87	8.68%				
2064	3575425		1687	3754737		0	0	0	0

Stream Type Comparison

Group 4						Group 5					
DNR			NHD			DNR			NHD		
STRM_TYPE= 20,21,22,62,63,80,90			FTYPE= 460, 558*			STRM_TYPE= 60			FTYPE= 558**		
Stream (Perennial), Stream (Intermittent), Stream (Unknown),			Stream/River, Artificial Path (*if not in NHDWaterbody)			Connector (Lake)			Artificial Path (**if not in NHDArea)		
Frequency	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**	**Frequency**	**Sum Length (ft)**	**% of Total**
1042	6426934.945	92.68%	1904	6426875.122	91.90%	49	159046.1172	28.47%	113	159040.9183	36.44%
640	34814.00257	0.50%	891	34604.69081	0.49%	48	1906.90231	0.34%	66	1886.267138	0.43%
499	13052.65112	0.19%	609	12848.22533	0.18%	48	1098.399204	0.20%	62	1072.752583	0.25%
412	9148.120346	0.13%	421	8738.854093	0.12%	47	1010.883908	0.18%	56	958.6193791	0.22%
362	3460.536638	0.05%	268	3032.577701	0.04%	46	260.6358205	0.05%	54	208.8318059	0.05%
322	1646.080507	0.02%	191	1092.495633	0.02%	46	241.7904756	0.04%	53	190.3175476	0.04%
314	1059.648665	0.02%	152	446.7407	0.01%	46	242.3377314	0.04%	53	190.1646301	0.04%
312	4833.769236	0.07%	145	1710.531276	0.02%	46	1387.040312	0.25%	53	1126.31231	0.26%
309	9061.800184	0.13%	141	2823.879578	0.04%	48	2549.104258	0.46%	54	2019.450151	0.46%
306	25241.80275	0.36%	140	7156.26602	0.10%	49	6046.741339	1.08%	52	4356.509055	1.00%
257	405601.8959	5.85%	289	493815.6693	7.06%	387	384885.8093	68.89%	50	265407.7257	60.81%
4775	6934855		5151	6993145		860	558676		666	436458	

Lake Geometry & Name Comparison

	Totals		Overlapping					
			Total			With Same Name		
	#	Acreage	#	Acreage	% of Total	#	Acreage	% of Total
DNR	1670	40,471.86						
NHD	3169	31,998.39						
Total	4839	72,470.24	841	29,204.70	40.30%	162	22,187.73	30.62%

Appendix 3c: Difference Testing Notes (DNR Comparison Test)

- related to *Chapter 3: Differences between the NHD and DNR Datasets*

DNR Hydrography vs. NHD: A DNR comparison by DNR major watershed (#60)

Testing performed by Lyn Bergquist, MNDNR, 02/06/14

Objective

This was a preliminary test by DNR to detect feature differences between the **NHD** and **DNR Hydrography** Datasets. Because the methods tested here didn't work well to compare datasets, another method (i.e., Buffer Test) was developed (see *Chapter 3* and *Appendices 3a &3b*). Information from this preliminary testing helped to inform development of the Buffer Test.

Streams Layers Compared (DNR Major Watershed #60)

- DNR Stream Routes with Kittle Numbers and Mile Measures
- NHD Flowlines

Observations

- Length statistics won't work to compare DNR vs. NHD flowlines due to very small rounding differences in the length calculations. Two linear features that appear to be identical are not seen as identical in ArcGIS; their lengths differ by 0.10 to 0.001, making *Select by Location: Identical Features* not a valid method.

- In order to compare NHD to DNR Hydrography, we need a current stream type layer that has the current stream and waterbody type codes and nodes at confluences. Prior to performing actual statewide synchronization, we will need to produce a stable DNR stream type layer using the newest hydro layers available. This may involve some reclassifying of how stream types are assigned. General process steps and considerations:
    - DNR kittle routes intersected with PWI, NWI or OW; assign lake connectors (artificial paths) in polygons; keep ditches, intermittent streams, other special types; create intersections at stream confluences
    - Question of what waterbodies to use for intersection (PW or OW? affects lake connectors)
    - Now that new NWI is available, should we use NWI polys for NHD wetlands? Open water? Public Water basins? Should DNR Hydro be updated completely with NWI prior to synchronization with NHD?
    - Question of whether to intersect with wetland polys (and what source to use); affects wetland connectors

STREAMS Strm_type	DNR HYDRO DB Description	FLOWLINE NHD FType	NHD Description
20	Perennial Streams	460	Stream/River
21	Intermittent Streams	460	Stream/River
22	Unknown Streams	460	Stream/River
40	Drainage Ditch (Perennial)	336	Canal/Ditch
41	Drainage Ditch (Intermittent)	336	Canal/Ditch
42	Drainage Ditch (Undifferentiated)	336	Canal/Ditch
60	Connector (Lake)	558	Artificial Path
61	Connector (Wetland)	558	Artificial Path
62	Centerline (River)	460	Stream/River
63	Connector (River)	558	Artificial Path
71	Underground Storm Sewer	428	Pipeline
80	Interpreted Arc Connector	558	Artificial Path
81	Arbitrary Flow Connector	558	Artificial Path
90	Superceded [sic] Natural Channel	558	Artificial Path
LAKES Wb_class (old DLG)	**DNR HYDRO DB Description**	**WATERBODY NHD FType**	**NHD Description**
108	Artificial Basin	???????	No code in NHD
106	Fish Hatchery Pond	46301	Reservoir Type - aquaculture
107	Industrial Waste Pond	43606	Reservoir Type - disposal - unspecified
105	Inundation Area	N/A	Use NHDArea not NHDWaterbody
610	Intermittent Water	39001; 46601	LakePond Intermittent or SwampMarsh Intermittent
-99999	Island or Land	???????	No code in NHD
421	Lake or Pond	39000	Lake/Pond
402	Mine or Gravel Pit	???????	No code in NHD
412	Riverine Polygon	N/A	Use NHDArea not NHDWaterbody
108	Reservoir	46300	Reservoir
109	Sewage/Filtration Pond	43612 43610 43611	Reservoir - treatment - Sewage Treatment Reservoir - Filtration Pond Reservoir - Settling pond
110	Tailings Pond	43604 43605	Reservoir - Disposal - Tailings Pond Tailings (Earthen) or Reservoir - Disposal -Tailings Pond
111	Wetland	46600	SwampMarsh

Table A3c-1. *DNR and NHD crosswalk for comparable stream and waterbody type codes.*

Test of pilot watershed: DNR Major 60 (HUC8 - 09020108) 2/7/14

Stream (Linear) Features:

- I selected all DNR streams and NHD flowlines that had their centroids within DNR HUC 09020108

- Totals: DNR (N=2295; 11333648.79 ft); NHD (N=3782; 11313473.14 ft); Difference: (+ 20175.65 ft for DNR)

- A *Select by Location* for identical features yielded no matches; "identical-looking" features differed by 0.001 to 0.10 feet.

- For each layer, I calculated the XY UTMs for the feature start, midpoint and end points. Values were calculated as Long Integers.

- I joined the attribute tables of the two layers on UTM_X_START and queried to find features from each layer where XY were the same for start, mid and end points and length difference = 0 (actually -1<=difference<=1). See **Figure A3c1**, next page.

    - These features were considered to be "identical" (within +/- 1 ft. resolution) N=1182
    - Features with same length but different flow direction (FLIP) N=42
    - Features with same length but some XY differences (CHECK) N=85
    - Features with length differences <= 3ft; XY are equal (CHECK) N=59
    - All features with length differences and many XY differences (CHECK) N=1703
    - All features with length difference > 5 ft (+/-) were flagged (CHECK) N=711

- I tested the following *ArcToolbox: Geoprocessing* operations to identify differences among stream features:
    - *ArcToolbox: Analysis Tools: Overlay:* ERASE, IDENTITY, INTERSECT, SYM DIFFERENCE
    - *ArcToolbox: Data Management Tools: Data Comparison:* FEATURE COMPARE

- None of these tools produced useful results for identifying differences among features

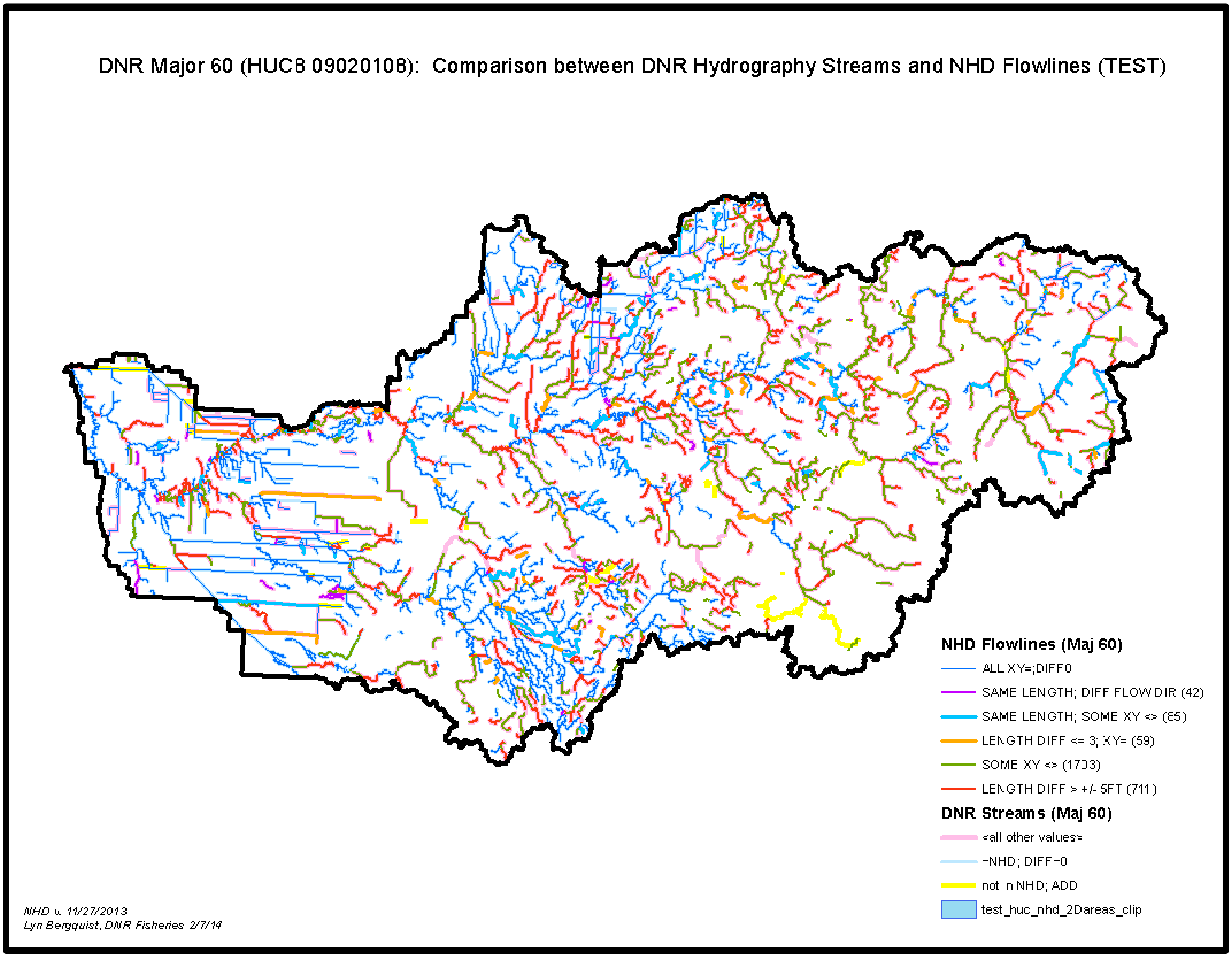

Figure A3c-1. *Results of DNR-NHD stream comparison by category.*

Conclusion

- There are many more differences between DNR streams and NHD flowlines than are apparent at first visual inspection, both in line length, starting/ending points and stream type attributes. The NHD dataset has many more and smaller features than the DNR streams dataset. Numerous small NHD stream segments may combine to equal one larger DNR stream segment; however, grouping by Reach ID or GNIS ID doesn't appear to be consistent enough to do mass matching of linear features based on an ID.

- None of the features are identified by ArcMap as being identical, even if they appear that way onscreen. Therefore, the tools to find identical features won't work for finding differences. Due to rounding differences in length, it was necessary to round to the nearest integer place in order to match lengths (feet) and X, Y UTMs (meters) among layers.

- Differences will continue even after the DNR stream types layer is regenerated using new lake polygons, because polygons have changed significantly since the creation of NHD. None of the existing layer polygons (OW, PWI, NWI) match the original 24K NWI used for the NHD waterbodies. Differences in lengths by stream types will continue after synchronization if DNR and NHD use different polygons to determine lake connectors. In addition, DNR may decide not to split up the stream types along all smaller wetlands (as was done in NHD).

- Although I'm not familiar with the NHD **conflation** process, I think it would be messy to use for adding DNR features to NHD in areas where features are dense. The probability of input features being matched to the wrong source features seems high. Therefore, I think that proper updating may need to occur on a feature by feature basis. This would be undoubtedly time-consuming but would offer the highest level of control.

- We will need an estimate (Chapter 4) on synchronizing based on a "typical" major watershed and then multiply by 81 major watersheds in Minnesota. Determine if we could split up the state and each (DNR, MnGeo) do some watersheds, marking potential conflicts for resolution by committee?

- Synchronization of streams involves both the matching of features and the matching of attributes. Due to the different stream types used in DNR and NHD, a crosswalk must be used to convert between the two layers.

- Following synchronization, sums of lengths by each stream type may be used to check overall synchronization success.

Lakes Layers Compared (DNR Major Watershed #60)

- DNR Open Water polygons; DNR Public Water polygons
- NHD Lake polygons

- ➢ NHD lakes generally match the original NWI (NWI – Cowardin Class Polygons) 1980-86
- ➢ DNR Hydro "open water" lakes are originally from the USGS DLG source; many have been re-digitized to match current air photos.
    - o For DNR lakes where source is original DLG polygon, these should be replaced with a more current re-digitized poly or an NWI polygon.
    - o Public Water (PW) polygons are delineated to the OHWL and are generally larger than the other OW sources.
    - o New NWI (2009-2014) are the most updated source, but can't always be neatly defined to correspond to OW and PWI delineations. New testing shows that classification upon the NWI attribute [LL_CLASS] may be promising for identifying OW polygons.
- ➢ Questions remain whether/how to update DNR Hydro OW and PW with new NWI features. A DNR Hydro update plan will be written by the DNR Water Resources Team to accomplish this.
- ➢ Questions remain which polygon source should be used for updating NHD. Since most DNR polygon events correspond to OW polygons, the OW would be desired choice for NHD <u>if</u> DNR is going to use NHD as its base hydro layer.
- ➢ Questions remain how PW and its derived products would exist if PW polygons are not used in NHD; under this scenario, <u>PW would need to be maintained separately</u>.
    - o A similar situation exists for OW polygons if PW was used as the new NHD source, although OW could potentially be stored as partial polygon events on PW polygons.
- ➢ An authoritative decision has to be made as to which polygon source to use for NHD.
    - o A benefit of using PW polys for NHD is that the delineations are more stable over time so there would be less future updating needed
    - o A disadvantage is that the delineations may not match air photos over time due to fluctuating water levels (users like to see GIS features match air photos; mismatching may lead to perceived inaccuracies of the NHD layer)
    - o Another problem may be the inability to reference DNR OW polys as events on NHD (however, partial polygon events may possibly be used)
    - o A decision may be made to leave out polygons smaller than a certain size and/or those not visible on current air photos
    - o DNR Hydrography datasets should be updated completely with new sources (new NWI, re-delineated polygons) <u>prior to synchronizing with NHD</u>

2D River (Polygon) Features

- The DNR hydro dataset has an incomplete set of river polygons; some have been re-digitized and others haven't. NHD generally has better river polygons than DNR.
- New NWI may be a good source to update both DNR Hydro and NHD.

References

Appendix 3a: Differences between the NHD and DNR Datasets (Buffer Analysis Methods)
– describes stepwise methods used to compare differences between NHD and DNR datasets in Chapter 3

Appendix 3b: Differences between the NHD and DNR Datasets (Buffer Analysis Methods)
- describes results from testing to compare differences between NHD and DNR datasets in Chapter 3

Chapter 3: Differences between the NHD and DNR Datasets

Chapter 4: NHD-DNR Dataset Synchronization (includes Resource Estimate)

Appendix 4: DNR vs. NHD Water Feature Type Comparison

related to Chapter 4: DNR-NHD Data Synchronization

DNR Open Water to NHD Waterbody

Highlighted DNR WB_Class rows below map to NHDWaterbody Feature

DNR Hydrography Open Water	WB_Class	Code	Maps to NHDWaterbody Fcode
	Artificial Basin		43600 Reservoir (Feature Type Only - no attributes) - could map to any # of reservoir types, if known
	Fish Hatchery Pond		46301 Reservoir Type - aquaculture
	Industrial Waste Pond		43606 Reservoir Type - disposal - unspecified
	Inundation Area		**Do not use (Maps to NHDArea, Fcode 40303 - Inundation Area - no attributes)** (32 features in DNR)
	Intermittent Water		39001 (LakePond Intermittent) or 46601 (SwampMarsh Intermittent) ??
	Island or Land		**Do not use (No island feature in NHD)**
	Island or land		**Do not use (No island feature in NHD)**
	Lake		39000 LakePond no attributes
	Lake or Pond		39000 LakePond no attributes
	Mine or Gravel Pit		*39000 LakePond no attributes - USGS has discussed mine pits as a separate Fcode
	Reservoir		46300 Reservoir - no attributes (USGS and DNR defs may be different - check this out)
	Riverine Polygon		**Do not use (Maps to NHDArea, not NHDWaterbody)**
	Sewage/Filtration Pond		43612 Reservoir - treatment - Sewage Treatment Pond or 43610 Reservoir - Filtration Pond- or 43611 - R Settling pond
	Tailings Pond		43604 Reservoir - disposal - Tailings Pond Tailings (Earthen) or 43605 Reservoir - Disposal -Tailings Pond
	Wetland		46600 SwampMarsh no attributes

DNR Open Water to NHDArea

Highlighted DNR WB_Class rows below map to NHDArea Feature

DNR Hydrography Open Water	WB_Class	Code	Maps to NHDArea Type
	Artificial Basin		Maps to NHD Waterbody
	Fish Hatchery Pond		Maps to NHD Waterbody
	Industrial Waste Pond		Maps to NHD Waterbody
	Inundation Area		**40303 - Inundation Area - no attributes** (32 features in DNR)
	Intermittent Water		Maps to NHD Waterbody
	Island or Land		**Do not use (No island feature in NHD)**
	Island or land		**Do not use (No island feature in NHD)**
	Lake		Maps to NHD Waterbody
	Lake or Pond		Maps to NHD Waterbody
	Mine or Gravel Pit		Maps to NHD Waterbody
	Reservoir		Maps to NHD Waterbody
	Riverine Polygon		**46000- StreamRiver - no attributes**
	Sewage/Filtration Pond		Maps to NHD Waterbody
	Tailings Pond		Maps to NHD Waterbody
	Wetland		Maps to NHD Waterbody

DNR Rivers and Streams to NHDFLowline

Highlighted DNR Strm_Type rows below map to NHDFLowline Feature

DNR Rivers_and_Streams	Strm_Long	Strm_Type	Maps to NHDFlowline Fcode
	Stream (Perennial)	20	46006 Stream/River - Hydrographic Type = Perennial
	Stream (Intermittent)	21	46003 Stream/River - Hydrographic Type = Intermittent
	Stream (Unknown)	22	46000 Stream/River - Unknown (do not know whether perennial or intermittent)
	Stream (Underground/Karst)	23	42000 Underground Conduit - (natural underground conduit associated with karst or lava flows)
	Drainage Ditch (Perennial)	40	33600 Canal/Ditch Hydrographic Type Unspecified
	Drainage Ditch (Intermittent)	41	33600 Canal/Ditch Hydrographic Type Unspecified
	Drainage Ditch (Undifferentiated)	42	33600 Canal/Ditch Hydrographic Type Unspecified
	Aquaduct (Elevated or Tunnel)*	43	33601 Canal/Ditch Type = Aqueduct (open)
			42801 Pipeline - Product = Water Type = Aqueduct Rel to Surface: at or near
			42802 Pipeline - Product = Water Type = Aqueduct Rel to Surface: Elevated
			42803 Pipeline - Product = Water Type = Aqueduct Rel to Surface: Underground
			42804 Pipeline - Product = Water Type = Aqueduct Rel to Surface: Underwater
			42816 Pipeline - Product = Water Type = Aqueduct
	Connector (Lake)	60	55800 Artificial Path
	Connector (Wetland)	61	33400 Connector
	Centerline (River)	62	55800 Artificial Path
	Connector (River)	63	55800 Artificial Path
	Road Culvert - flow conveyance feature	70	42814 Pipeline: Pipeline Type: general use *Not Sure*
	Underground Storm Sewer	71	42823 Pipeline: Pipeline Type = Stormwater , Underground
	Force Main	72	**No current feature in NHD**; use general stormwater?
	Drain Tile	73	**No current feature in NHD**
	Interpreted Arc Connector	80	33400 Connector
	Arbitrary Flow Connector	81	33400 Connector
	Superceded Natural Channel	90	None. Use Stream/River 46000

* Notes: Use 33601 if open, 428xx Pipeline-Aqueduct if closed

Appendix 6a: ArcGIS Topology for Editing - Geodatabase Topology vs. Map Topology

- related to *Chapter 6: Maintenance Model Options – Option #1*

Geodatabase Topology vs. Map Topology

Overview

To edit features in ArcMap that share at least part of their geometry, you need to use topology. There are two kinds in ArcGIS: **map topology** and **geodatabase topology**. Creating a map topology is quick but simply allows you to edit features that are coincident. A geodatabase topology requires more effort to set up and modify, but it allows you to more precisely define complex relationships about how the features in one or more feature classes share geometry.[i] To use either type of topology for editing in ArcMap:

1. **Start editing** on layer of choice
2. On the Topology toolbar, click **Select Topology** 
3. If you've previously set up a **geodatabase topology** then you will have a choice between it and a **map topology** in the subsequent Select Topology dialog:
    a. **Map Topology** requires you to choose those layers that you want to participate and allows you to set the cluster tolerance (the minimum allowed distance between vertices). Since a map topology is based on the layers in the map, layer visibility, such as definition queries and scale ranges, is respected. Only visible features are edited when you use the topology tools with a map topology.[ii]
    b. **Geodatabase Topology**, on the other hand, needs to be set up before you can do edits in ArcMap. This can be done in ArcCatalog or ArcToolbox and is where the layers, cluster tolerance and topological rules are chosen.

For a **geodatabase topology**, all of the tools on the Topology toolbar are enabled while for a **map topology** the last four tools: Validate Topology in Specified Area, Validate Topology in Current Extent, Fix Topology Error and Error Inspector tools are disabled.

One potential advantage of a **map topology** is that not all layers have to share the same **feature dataset** like they do for a **geodatabase topology.** Therefore, for example, you could snap one line feature class to another in a separate feature dataset.

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[i] ArcGIS Resources, ArcGIS Help 10.2, 10.2.1, and 10.2.2, http://resources.arcgis.com/en/help/main/10.2/index.html#//01mm0000001m000000.
[ii] ArcGIS Resources, ArcGIS Help 10.2, 10.2.1, and 10.2.2, http://resources.arcgis.com/en/help/main/10.2/index.html#//01mm0000000r000000.

Appendix 6b: ArcGIS Workflow Manager

- related to *Chapter 6: Maintenance Model Options – Option #1*

Objective

ArcGIS Workflow Manager was considered as a potential strategy for managing pre-notification, review, conflict resolution and approval tracking of proposed edits to NHD (see **Chapter 6: Maintenance Models, Option #1**). It appears to offer many of the essential tools needed to effectively manage the distributed maintenance workflow among partner agencies. Although Workflow Manager was not specifically tested for Option #1, its properties were reviewed for potential use for future synchronization and maintenance efforts. Highlights of ArcGIS Workflow Manager are summarized below.

ArcGIS Workflow Manager can be used to:

- Improve user productivity by automating common activities such as geo-processing, version management and reducing repetition of production procedures.
- Ensure standardization and consistency across operations by quickly creating workflows using simple visual tools and centralizing workflow management.
- Automate and simplify workflow management using out-of-the-box, user-configurable tools.
- Easily track workflow status using reports.
- Integrate your GIS and other business applications by seamlessly incorporating non-GIS activities into your GIS workflows.
- Efficiently manage a dispersed workforce and assign activities by geography.

SOURCE: ESRI website at: www.esri.com (2014)

ArcGIS Workflow Manager…

- Will allow you to track your work
  - Can document what needs to be done and why
  - Can add notes while executing a workflow step
  - Can attach a screen grab
  - Can open the activity log to see who did what, when and if it was successful
    - This info is stored in a centralized location and you can generate reports from it
    - Can mine this using some of the existing built-in reports within Workflow Manager

- Helps you enhance communication
    - Can send emails when things happen on a job or when a workflow step is executed
    - Send a detailed description of what happened on a job
    - Can create your own notifications within your organization
    - Make sure people know when they have work waiting for them to be done
    - Provide real-time status to stakeholders

- Can model more intelligent behavior into your workflow process
    - Add decision points
    - Automatically assign a certain piece of the workflow to a particular group
    - Can model relationships with your job so you can have a job be dependent on another job
    - Can automate some processes like map creation and geo-processing tasks

- Desktop version and Server version
    - Manage versions better if you use them

- Version management for multiuse editing environment
    - Automate the creation of versions and automate the deletion of versions
    - GDB archiving allows you to bridge between geodatabase archiving event or edits to a particular job
    - Better way to track edits – who did what, what happened

- Job information tab allow you to enter a step description or link to a document to help with documenting what happens at that step

- Workflow manager allows you to assign particular steps or paths to specific people so they will be notified when the data needs to be updated due to changes in the main dataset.
    - Assign privileges, so can control what they can or cannot do
    - Can restrict editors to specific geographic areas
    - Can provide specific directions for how to do the work that needs to be done
        - They can link existing documents here for documenting why changes were made
        - Can launch a geo-processing tool or model

- Can update maps once workflow steps are completed

SOURCE: ESRI 2011 User Conference (video presentation)

Appendix 7a: State Communication and Coordination Plan

- related to *Chapter 7: Option Testing and Results*

Background: Coordinating Updates at the State Level

Appendices 7a *(State Communication and Coordination Plan*) and **7b *(NHD Stewardship)*** were written specifically to support "Maintenance Option 2 - Direct Editing to the NHD" (by all state partners). However, a plan for state coordination and communication will be needed regardless of the option chosen, as outlined in the last section of this appendix.

The NHD Stewardship activity prescribes a national process for tracking and coordinating updates. Where there are multiple organizations within a single state that plan to edit the NHD, USGS sets in place certain rules, but otherwise leaves it up to individual states to determine their own coordination and communication policies. This appendix proposes a state communication and coordination process to be used in conjunction with NHD Stewardship.

The NHD Stewardship process defined by USGS is outlined in **Appendix 7b**. The State Administrative Steward (or Principal Steward) receives communications from the designated USGS NHD Point of Contact (POC), participates regularly in NHD Advisory Team phone conferences, and follows developments and discussions on the NHD "Confluence" website. This enables the State Administrative Steward to stay current on NHD issues including impending model changes, problems, fixes, and USGS plans for global edits.

The national NHD Stewardship process assures that the Principal Steward and USGS POC are notified when a checkout for editing occurs, that no two organizations can check a subbasin out for editing at the same time, and that all participating stewards can view the editing status for the state's subbasins. The USGS notification system, therefore, lets the Principal Steward know of editing activity AFTER the fact.

However, with multiple organizations potentially editing NHD in Minnesota, the Minnesota user community sees the need for a more proactive state role. To function effectively, the Minnesota NHD Editor community would need to set in place two main functions:

- A means for two-way communication on NHD issues that would assure that national NHD discussions filter down to the state editor community and that state comments and concerns get communicated back to the national work group. This mechanism should also enable state hydrography editing participants to share information about any editing issues that are important to them, resolve questions, and evaluate best practices in response to new situations.

- A means for communicating state-level intentions to edit **before** editing sessions occur, so that other organizations can plan accordingly; and a means to review as a group, and pre-approve, proposed edits the NHD.

State NHD Stewards General Information Dissemination Activity
(State Communication and Coordination)

Purpose: The State Administrative Steward is the main point of contact in the state for the USGS NHD Team. The purpose of this activity is to make sure that the information available to the State Administrative Steward about NHD activities is forwarded to all sub-stewards and other interested parties, and that concerns of state-level NHD editors are relayed to the national NHD Team. In particular,

- Federal-to-state communication: information to be disseminated could include model changes, problems and fixes, planned global edits, NHD Advisory Team discussion topics (e.g., for model changes involving the addition or deletion of feature types), as well as editor checkouts and check-ins through the NHD master database at USGS.
- State-to-federal communication: concerns of the state user community need to be gathered by the State Administrative Steward and communicated to the national NHD Team; state users need to be part of the bigger discussion as needed; and they need to know how those issues are responded to nationally.
- General issues regarding hydrography editing that state partners feel the need to discuss, including evolving best practices for editing as new background data becomes available.

Process: Methods for general information distribution, group discussions, and feedback can include the following:

- **Minnesota NHD Editor Working Group**: A "Minnesota NHD Editor Working Group" should be created and supported by the State Administrative Steward as an umbrella for state NHD stewardship.
- **Email group:** A two-way email group or list server is set up for basic information dissemination of national NHD activities, questions review, planned edits, and requirements for pre-edit approvals
  - State Administrative Steward uses email group to distribute key information about state activities, training opportunities, and NHD issues as discussed in the Advisory Team meetings to its sub-stewards (SS) across the state
  - State stewardship community uses email group to submit comments and questions, discuss issues of delineation policy, start discussions on planned edits etc.
- **Phone conferences:** A regular schedule of "Minnesota NHD Editor" phone (WebEx) conferences can improve communication among the Minnesota editor community. An appropriate frequency of phone conferences need to be established which may depend on the amount of editing occurring. If in WebEx format then these meetings could also support the pre-approval process.
- **Annual meetings:** An annual Minnesota NHD Editor meeting could be used as to review the data and the process and planned activities and to gather feedback on whether the system is working and how to improve it.

State NHD Stewards Editing Pre-notification and Pre-approval Activity

Purpose: Set up a notification and pre-approval process so that all stewards within a state are aware of the planned editing regions by any steward and can review planned edits BEFORE they are completed and submitted to USGS.

- **Distribution of editing activity in Minnesota:**
  - USFS edits only in subbasins containing portions of the Chippewa or Superior National Forests.
  - MPCA, DNR, and most other sub-stewards would edit across the state.
  - Border subbasins have other constraints discussed in Appendix 7b. They may require consultation with another state or province.
  - USGS may do global edits, or edits in the absence of a robust stewardship activity in the state. (The more the state is capable of taking over these edits, the less USGS will have to do, and the more control the state has.)

- **Editing units:**
  - Editing generally will be done at a HUC-8 (subbasin) level.
  - Future updates assisted by LiDAR to create a higher-resolution, more dense drainage network will probably be done on smaller drainage units (HUC-10 or -12).
  - Editors should check out the smallest unit feasible so that they can turn around the edits and get them back into the national database as quickly as possible.

- **Pre-notification of editing activity in Minnesota:** Given that most editors could work anywhere, pre-notification of editing activity is desirable for several reasons:
  - *Planning and scheduling of edits:* knowing that another organization wants to edit in the same HUC-8, and how long they have it checked out for, so that wait times for access to a HUC for editing are minimized.
  - *Improving efficiency of editing efforts:* if two agencies have needs to edit in the same area, perhaps one editing agency can perform the edits for both agencies. There may be no need for two organizations to edit the same subbasin if the first organization can be advised as to the edit needs of the second if the editing needs are well-defined and clear-cut.
  - *Planning for event maintenance:* if an organization is planning to create a new set of events, or update existing events, then knowing that edits are occurring in an area can be important to scheduling the event maintenance efforts.

- **Pre-approval of NHD edits for Minnesota:** Beyond pre-notification of editing activity, this project team has identified the need for a pre-approval of edits before they go to USGS. There are a number of benefits to a pre-approval process:
  - The ability to review as a group the planned edits and agree on which changes need to be made, and how. USGS has established the NHD delineation rules, and the state has established the state's synchronization rules *(Chapter 4)* that describe how DNR and NHD

delineations need to come together. There will always be a need to edit the data in the future as the hydrology on the land changes and improved data enables better delineations. It is helpful for all agencies to what edits are proposed, that they agree with them, and they are not negatively affected by them.

    - The development of a level of comfort with the editing that other organizations perform on features that Minnesota's organizations all share.
    - The development of an understanding of how an edit one agency makes could affect others. *For example:*
        - For DNR, knowing how the editing of the NHD "primitives" (stream flowlines, open water lakes) would affect their own derived data sets.
        - For MPCA, knowing how the editing might affect flowline or waterbody events.
        - For USFS, knowing how lake boundary editing might affect their FSTopo maps, which include both hydrography and manmade recreational features.
    - Avoidance of a situation where one agency's edits inadvertently "undo" an edit that another agency has made.

- Note that other states' stewardship groups have confronted the same issue, in particular, the Alaska Hydro group, and the Pacific Northwest Hydrography Framework (which involves state and federal agencies in Washington and Oregon). The Pacific Northwest Hydrography Framework group also has a stewardship review process, at least for areas of adjacent or overlapping editing. However, this group distinguishes between "minor" and "major" edits. Only the "major" edits are subject to pre-approval review. Minnesota may want to do something similar once the agencies have more experience with NHD editing and the review and coordination of edits.

Communication Process

- Use an email group to notify every one of planned edits, and the scheduled phone conferences to discuss and review those edits. To visualize these future activities, develop a web mapping application such as ESRI's ArcGIS Online.[i]

- Use a web mapping application such as ArcGIS Online (AGOL) for editors to display and describe general areas of planned edits on a state map.

- Use a web mapping application such as ArcGIS Online (AGOL) as a means for editors to display actual planned edits so that the user community can review and approve.
    - In AGOL an NHD Editor Application would be set up with a set of background layers: current version of NHD, imagery, LiDAR, current DNR derived layers, etc.
    - Editors could upload a file into AGOL that would represent the planned edits, for the full state editing group to review. The data set should include a field for editor comments and multiple fields for reviewer comments.
        - Reviewers could be given a deadline to review all proposed edits and sign off on them.

        - A WebEx or Lync meeting could be scheduled to go over the edits and approve/disapprove as a group. Experience with WBD edits has shown that it often does take a meeting to get the review completed.
    - Review and approval:
        - Edits that are approved by all can be immediately completed in the standard NHD Desktop Editing environment.
        - Edits for which there are questions need to be researched and resolved **quickly** so that actual editing is not held up.
        - Possibly set up tiers of edits: "minor" edits that no one else needs to review; "major" edits that everyone needs to look at.
        - Major disagreements would be submitted to a special review board, or hydrographic arbitration board (including members of all the involved agencies), which was set up specifically for this purpose, to make a final decision. Major disagreements should be infrequent.
    - Alternatively, a shapefile of planned edits could be distributed to all editors for review, or placed in the GDRS.

Applicability to Maintenance Options 1 and 3

This appendix proposes a state coordination and communication process specifically to support "Maintenance Option 2 - Direct Editing to the NHD" (by all state partners). However, a plan for state coordination and communication will be needed regardless of the option chosen. Most of the process described above could also be adapted to the state coordination requirements for maintenance options 1 and 3, or for a hybrid approach:

- In maintenance option 1 (shared editing of an SDE database) versioning takes care of reconciling differences between edited versions of linework, but there is still need for re-notification and general communication about plans and best practices.
- In maintenance option 3 (maintaining current business practices) all agencies except DNR need to communicate, as described in this appendix, as editors of the NHD. Because DNR would be editing their own set of linework, is doubly important that a strong communication and coordination plan is carried out.
- The "Minnesota NHD Editor Working Group" could become simply the "Minnesota Hydrography Editor Working Group ".

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[i] The pre-notification and pre-approval processes could be assisted by a web-based map viewing application such as ESRI's ArcGIS Online. There may be other applications available that could provide the same type of support. However, Minnesota state agencies have this software available to them, and testing for this project was performed using ArcGIS Online.

Appendix 7b: NHD Stewardship Process

- related to *Chapter 7: Option Testing and Results*

Overview

This appendix describes the **NHD Stewardship** Process as prescribed by USGS, and additionally covers questions which potential Minnesota NHD editing partners have asked about. General Stewardship process topics include:

- The NHD Stewardship Process – Organizational Overview
- USGS Process for signing up and training stewards and sub-stewards
- USGS Coordination of update process: Data Checkout and Check-in
- Coordinating updates at the state level
- USGS stewardship resources

Additional topics covered include:

- Interstate Editing Issues
- US- Canada Editing Issues (International Data Harmonization Efforts)
- Managing Geographic Names
- NHD-WBD Stewardship
- Past State NHD Editing History

NHD Stewardship Process – Organizational Overview

The United States Geological Survey (USGS) manages the national framework hydrography data layer, the NHD. USGS maintains the national version of the database, and the stewardship process manages updates to the data that come from a large number of federal, state, and local partners. USGS defines and evolves the data model, stores and distributes the master NHD database, develops NHD editing tools and quality control checks that maintain the integrity of the data model, and manages the flow of updates to the national data set. A community of users becomes the steward of the data.

An "NHD Management Team", consisting of USGS and other federal agency NHD users and a small number of state representatives, guides the overall direction and development of the NHD.

NHD Technical Points of Contact (POC) are USGS staff assigned to work with states.

At the state level, an NHD "State Administrative Steward" (SAS) or "Principal Steward" (PS)[i] needs to be formally designated. The State Administrative Steward serves as the state's primary Point of Contact for the USGS NHD Team, and the locus of two-way communication between state organizations and the USGS. Communication involves questions about the content of state's NHD, the state's plans for editing the NHD, USGS plans for editing the NHD over the state's area of interest, and various policy and tool development issues that USGS is pursuing. The State Administrative Steward is also the primary state contact on issues for watersheds that span interstate and international boundaries.

USGS requests that a formal Stewardship Agreement should be formulated and signed between each state and USGS. The State Administrative Steward can be an active editor of the NHD or simply serve as a coordinator or "gatekeeper" for the state's NHD edits.

Minnesota needs to designate a State Administrative Steward, or Principal Steward, for the NHD in Minnesota, and formally sign an NHD Stewardship Agreement with USGS. (MnGeo has served in this role in the past, but without a formal signed agreement or consistent funding to support the role.)

Multiple organizations can serve as sub-stewards (editors) of the NHD within a state's borders. USGS asks that sub-stewards work through (and be recognized by) the State Administrative Steward. USGS further requests that federal agencies wishing to edit NHD within a state's jurisdictional area be formally recognized by the State Administrative Steward as an editor of the NHD. The State Administrative Steward must assure that sub-stewards are kept apprised of information circulated by the USGS through its various communication mechanisms, and forward the concerns of the sub-stewards to the USGS.

The State Administrative Steward and sub-stewards must follow all of the practices defined for NHD updating and management by the United States Geological Survey's NHD Team.

- Policy, tools, database definitions, and edit processes and procedures are defined by USGS on their NHD web page - http://nhd.usgs.gov.
- Data checkout and check-in for purposes of updating is tracked by USGS through the NHD Stewardship web page - http://usgs-mrs.cr.usgs.gov/stewweb/.
- Each state has been assigned a USGS NHD Team Point of Contact (POC). The POC is the primary staff contact for the state. USGS NHD POC's have responsibility for a number of states. Minnesota's POC is Joel Skalet (jjskalet@usgs.gov).

USGS communicates with the stewardship community through a number of means:

- The NHD website and NHD Stewardship websites
- The USGS Confluence website: a controlled-login space which serves an NHD User Community forum and shared-document space, stores documentation and enables communications among users on issues relating to the NHD and NHD tools.
- Weekly "NHD Advisory Team" phone conferences, which are used to keep the user community current on NHD issues including impending model changes, problems, fixes, and USGS plans for global edits. This is also the forum for users to ask questions, register complaints, and provide feedback as requested by USGS on NHD issues. Federal agencies and State Administrative Stewards generally participate in these calls, although participation is not limited to those organizations.

At the state level, the State Administrative Steward and potential sub-stewards can set up any additional agreements, notifications, or processes that they need to coordinate the work of editing the NHD within the state's border.

USGS also has its own staff of NHD editors. These editors perform edits in those areas where there is no active stewardship going on (for instance, updating hydrography features against new imagery for topographic map revision). They also periodically perform global updates to the NHD for specific purposes: model updates, general maintenance (minor fixes), names updates, updates to match updated watershed delineations. For some of these updates (e.g., topo revision or minor data fixes), USGS first offers the state steward the opportunity to perform the updates. If the steward is unable to do so within a near time frame, then USGS will make the edits.

USGS Process for Signing up and Training Stewards and Sub-Stewards

- Stewardship sign-up and activity is activated through the NHD Stewardship web page: http://usgs-mrs.cr.usgs.gov/stewweb/
- State Administrative Steward is assigned privileges by the state's NHD-POC. State Administrative Steward account is set up with roles as "Principal Steward" and "NHD Editor".
- In order to become NHD editors or sub-stewards and to be able to extract data for NHD Editing, people/organizations must create an account on the NHD Stewardship web page and ask to be approved as an "NHD Editor". Staff from MPCA, DNR, and USFS and other interested agencies could create an account.
- Once a new sub-steward account has been set up by a user, the USGS staff Point of Contact for Minnesota is notified. The POC verifies with the State Administrative Steward/ Principal Steward that that person/organization should be granted editor role. Upon confirmation, the POC sets up the NHDEditor permissions for that account.
- Persons approved as editors need to take the NHD editor training, which is web-based. To schedule training they need to contact the state POC.
- Editing is done on the editor's desktop using the NHD Update Tools. Prior to the April 2012 release of NHD Update Toolset v. 4.0.0, this toolset was known as the "NHDGeoEdit" Tool. [ii]
- After taking editor training (and before doing "real", or permanent edits), editors can check out data from "Stewardship ***beta***" web site (http://usgs-mrs.cr.usgs.gov/stewardbeta/). These are test edits for training purposes and are not submitted back to the national NHD database. Once comfortable with the editing process, editors can check out data for editing from the main stewardship website.
- Before doing any "real" editing, sub-stewards need to check with the State Administrative Steward and discuss their intended edits. One of the outcomes of this project is a state communication and pre-notification process that would help coordinate edits made by different organizations around the state.
  - Some states divide up the state by watershed
  - Some states have multiple sub-stewards all able to edit all over the state, requiring a state coordination strategy.
- The NHD Stewardship website (http://usgs-mrs.cr.usgs.gov/stewweb/) contains a number of sections, including account creation, a description of the stewardship process, a training schedule, the opportunity to request maintenance, general announcements, and training demo videos. Once a steward or sub-steward has an account set up with approved editor roles, that

user is able to download tools, and to check one or more subbasins for editing via the web map interface. NHD editing is done on the editor's desktop.

USGS Coordination of update process: Data Checkout and Check-in

- The NHD Stewardship website (http://usgs-mrs.cr.usgs.gov/stewweb/) controls the checkout of subbasins for editing. As part of the checkout process, the editor fills out a web form that identifies the state, the editor, the subbasin (HUC-8)[iii], the types of intended edits, the checkout date, and the estimated completion date.
- USGS Stewardship process assures that only ONE entity can check out a subbasin at a time. Once that subbasin in checked out, no one else can check it out for editing until those edits are completed and the subbasin is checked back in. This is to minimize the number of conflicts that could potentially arise from two editors independently editing the same features. The Stewardship website online map shows what has been checked out, who is doing those edits, what the edits are, and planned edit completion date.
- The State Administrative Steward and USGS POC receive an email from USGS every time a subbasin of interest is checked out by anyone. (Checkouts can sometimes be by another state which shares the subbasin or by the USGS when they make more global updates to the data). The State Administrative Steward and USGS POC also receive a notice when the job is complete and the edited subbasin is checked back in.
- Since a subbasin checked out for editing cannot be edited by anyone else, editors are encouraged to complete their intended edits quickly once they have checked a subbasin out. Editors start receiving email reminders if their subbasins are checked out past their stated completion date.
- Edited data checked back in to the NHD go through a reconciliation and posting process at USGS, and then the edited data is available through web services and the NHD distribution system in 1-2 days.
- There is a USGS stated goal of providing 10-day turnaround after editing for full state extracts containing those edits.

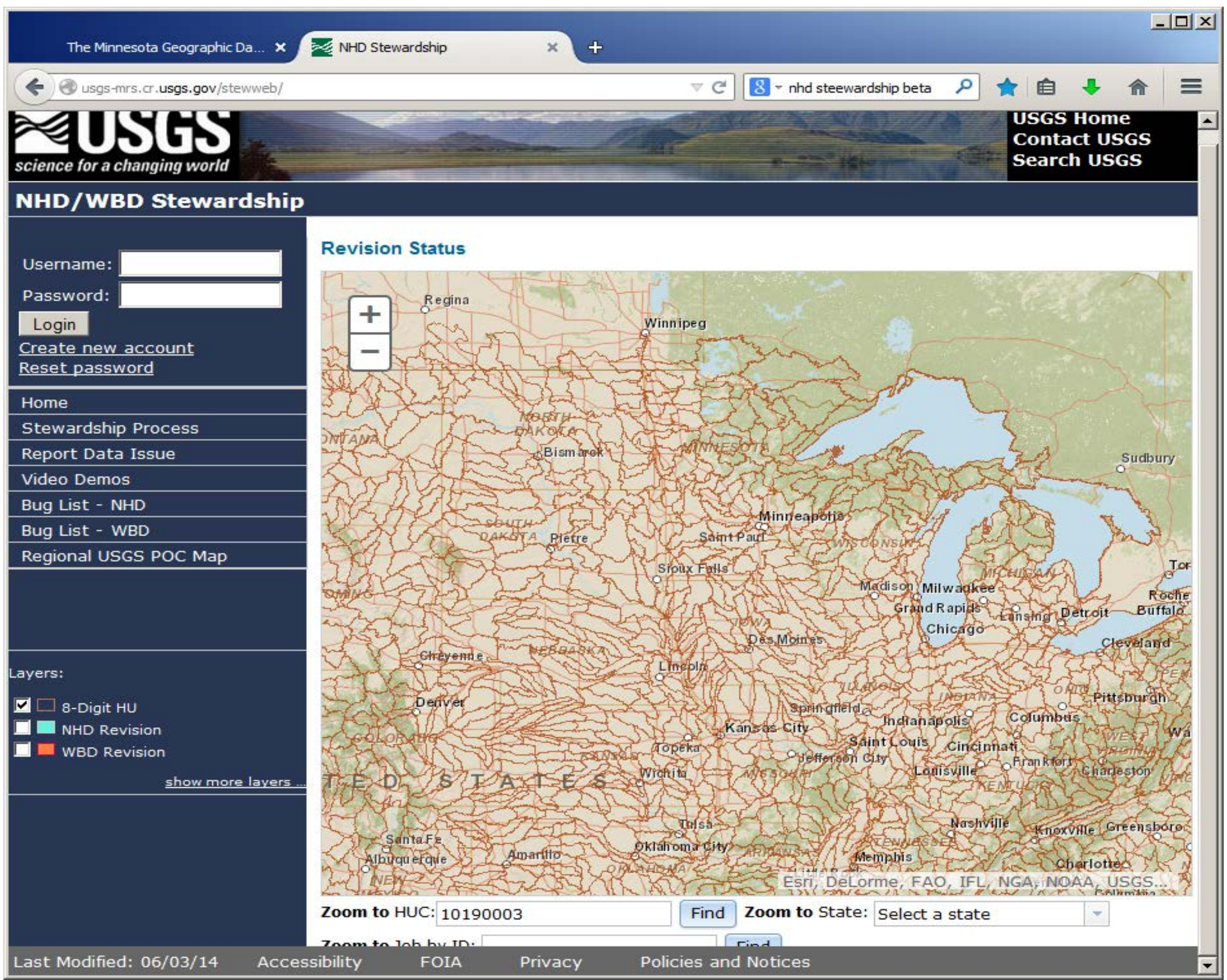
Coordinating Updates at the State Level

At the state level, the State Administrative Steward and potential sub-stewards can set up any additional agreements, notifications, or processes that they need to coordinate the work of editing the NHD within the state's border, and with neighboring states.

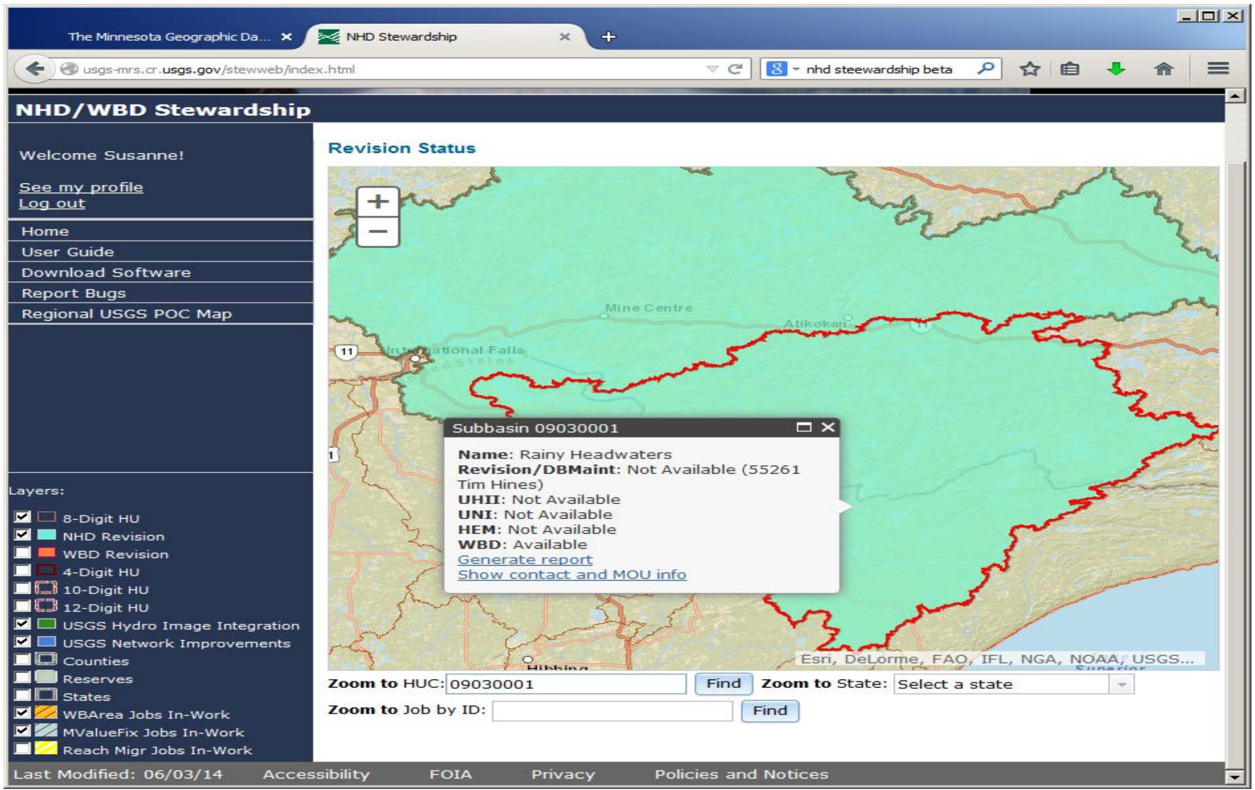
Stewardship Resources

- The main USGS web page (http://nhd.usgs.gov) provides access to:
  - **Data downloads** – or multiple subbasin (on the fly) extracts, prestaged subregions (HUC-4's) and state extracts, stream gage and dam extracts, web map services. These extracts are NOT for NHD editing; NHD editors use a different process to access the data.
  - **User resources**, which include an NHD User Guide, Videos, Fact Sheets, an annotated Feature Catalog, Model definitions and templates, and Concept Documents
  - A means to report data errors to USGS (assuming that the reporting agency is not an editor and just wants to see the error fixed.
- The NHD Stewardship web page (http://usgs-mrs.cr.usgs.gov/stewweb/) - requires an NHD Editor account to get access to most of the functions:

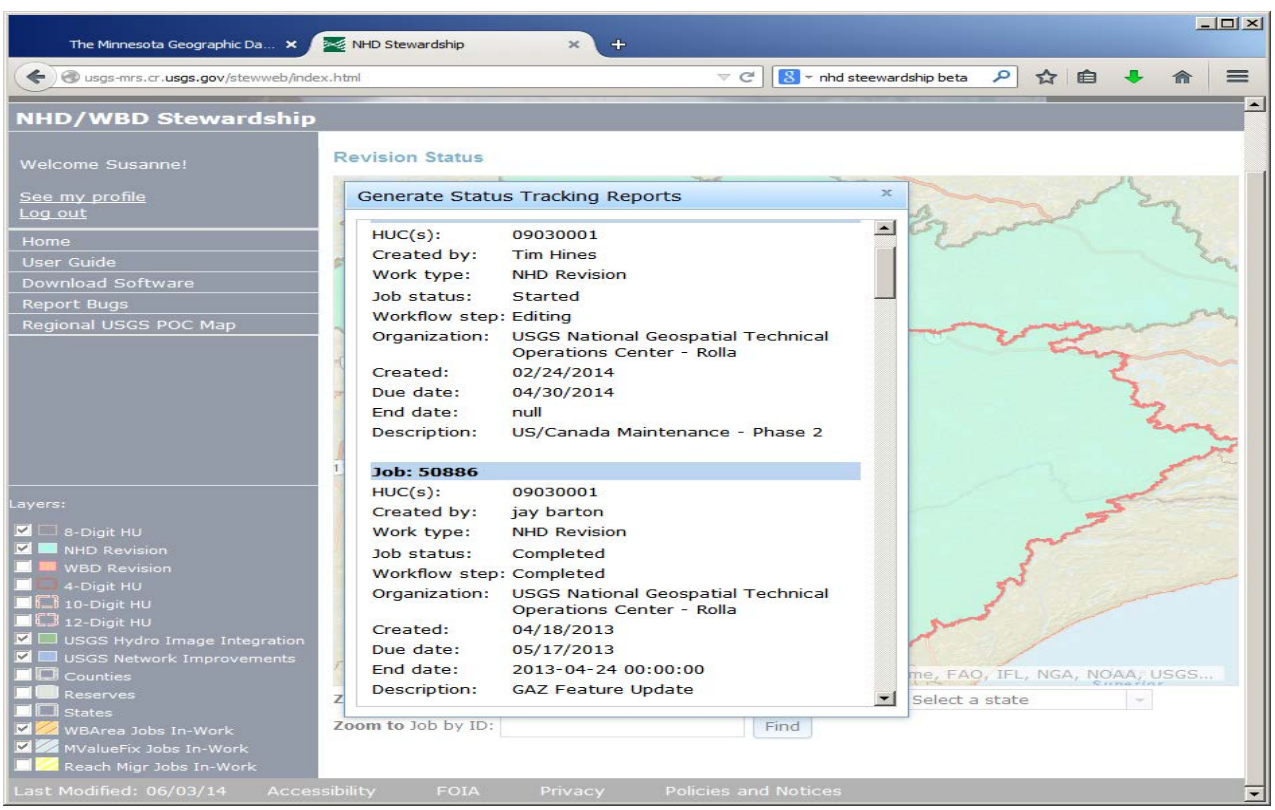
The NHD Stewardship web page before login:



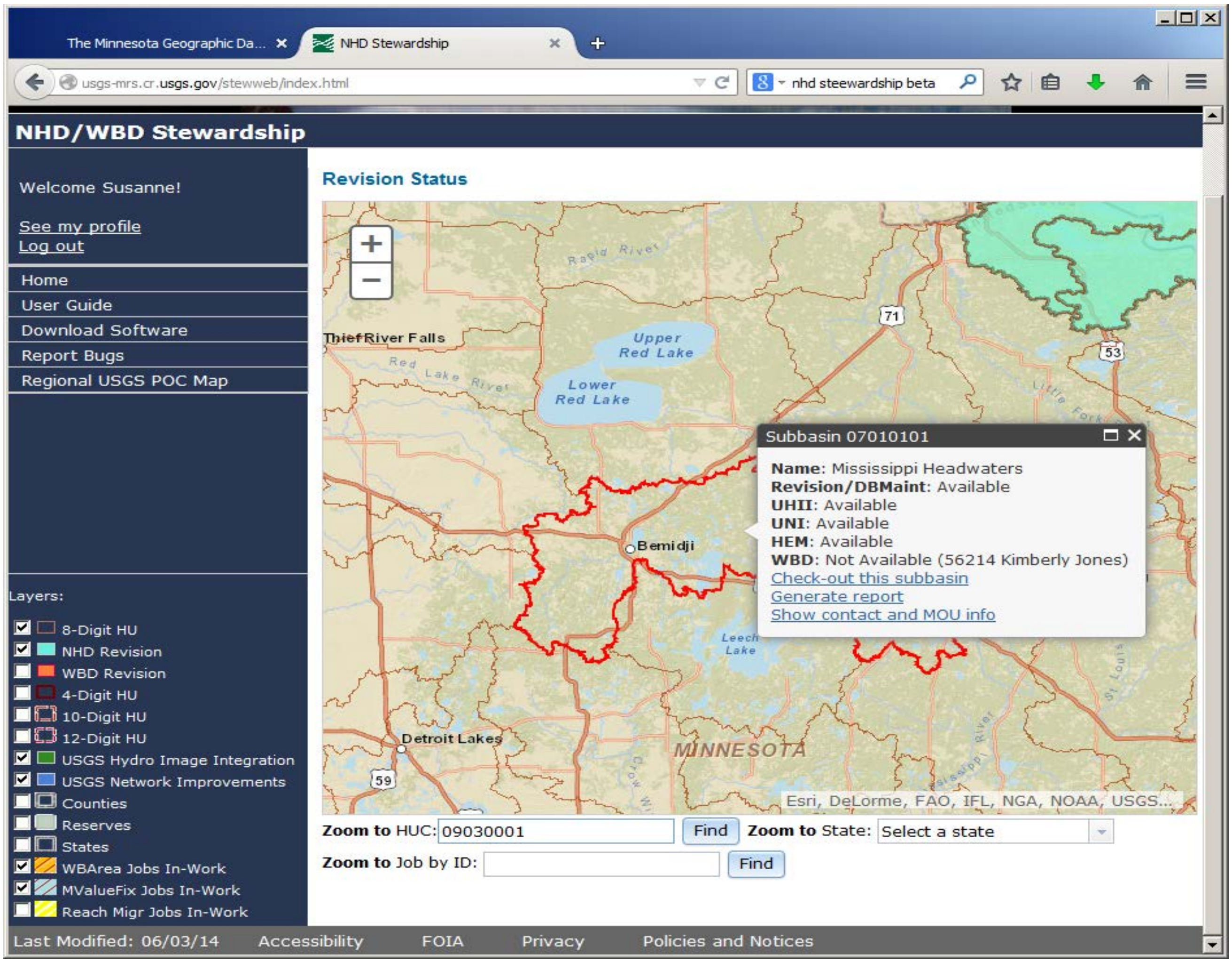
Access to the NHD Stewardship web page after login to stewardship account – notice that subbasin 09030001 is checked out to another user.



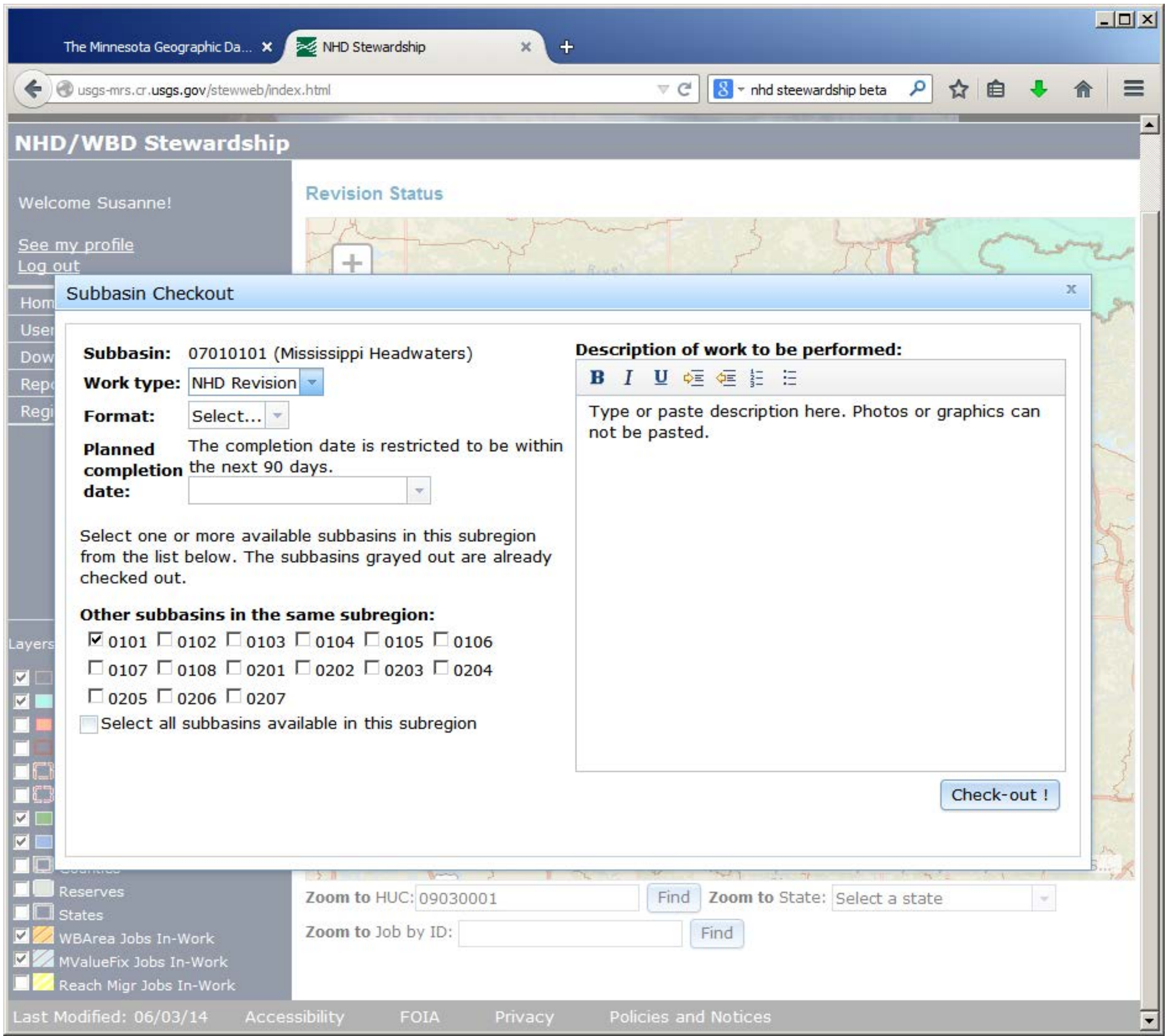
Generated Report on Editing History. Can specify the reporting period. Report starts with most recent edit session.



Checking out a new subbasin for editing:

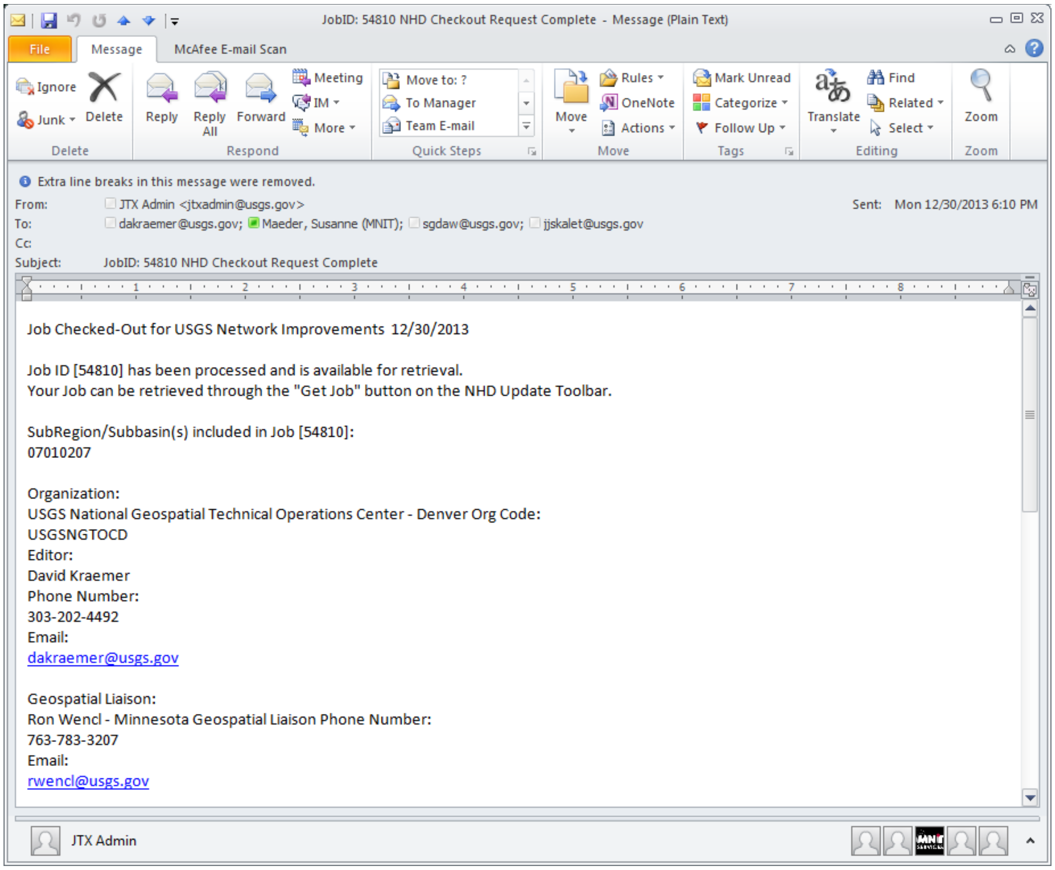


Explaining your edits:



Identify which subbasin(s) will you edit; what is the work type; when edit will be complete (the sooner the better!); description of the type of edits to be performed. The “checkout” extracts the dataset (as a replicate checkout from the USGS database). Once the checkout is completed, the edit record is stored with the name of the editor, State Administrative Steward, and state USGS POC. Editor, State Administrative Steward, and POC are notified when the data is checked out, when the checkout dataset is available, and when the edit job has been completed and the data has been checked back in.

USGS Automated Notification (via JTX): checkout notice:



JobID: 54810 NHD Checkout Request Complete - Message (Plain Text)

Extra line breaks in this message were removed.

From: JTX Admin <jtxadmin@usgs.gov>

Sent: Mon 12/30/2013 6:10 PM

To: dakraemer@usgs.gov; Maeder, Susanne (MNIT); sgdaw@usgs.gov; jjskalet@usgs.gov

Cc:

Subject: JobID: 54810 NHD Checkout Request Complete

Job Checked-Out for USGS Network Improvements 12/30/2013

Job ID [54810] has been processed and is available for retrieval.
Your Job can be retrieved through the "Get Job" button on the NHD Update Toolbar.

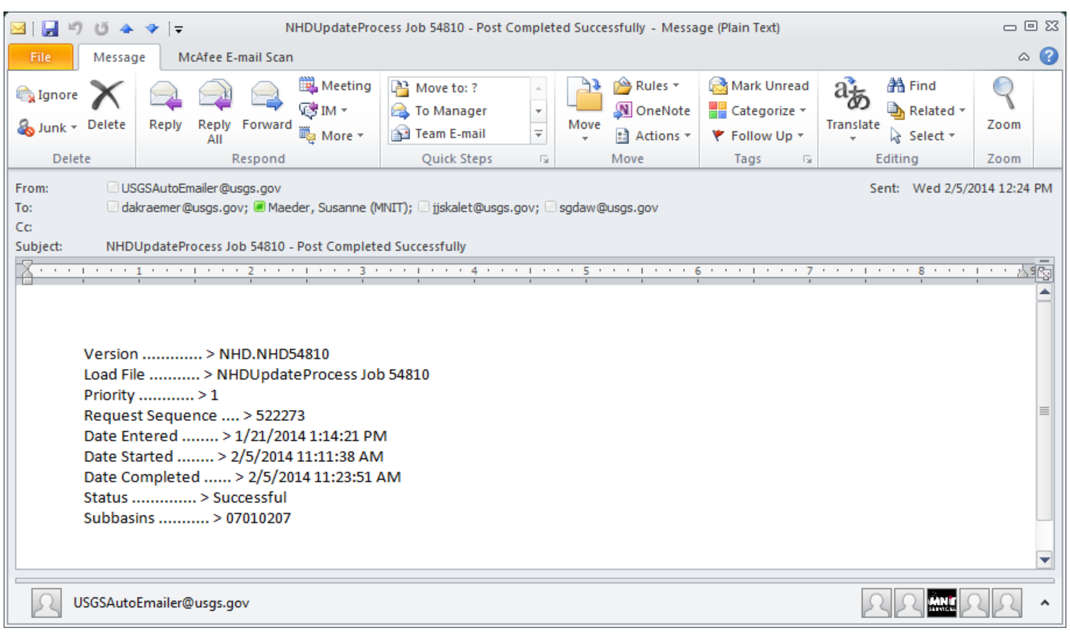
SubRegion/Subbasin(s) included in Job [54810]:
07010207

Organization:
USGS National Geospatial Technical Operations Center - Denver Org Code:
USGSNGTOCD
Editor:
David Kraemer
Phone Number:
303-202-4492
Email:
dakraemer@usgs.gov

Geospatial Liaison:
Ron Wencl - Minnesota Geospatial Liaison Phone Number:
763-783-3207
Email:
rwencl@usgs.gov

JTX Admin

USGS Automated Notification (via JTX): Job completed (check-in) notice:



NHDUpdateProcess Job 54810 - Post Completed Successfully - Message (Plain Text)

From: USGSAutoEmailer@usgs.gov

Sent: Wed 2/5/2014 12:24 PM

To: dakraemer@usgs.gov; Maeder, Susanne (MNIT); jjskalet@usgs.gov; sgdaw@usgs.gov

Cc:

Subject: NHDUpdateProcess Job 54810 - Post Completed Successfully

Version .... > NHD.NHD54810
Load File .... > NHDUpdateProcess Job 54810
Priority .... > 1
Request Sequence .... > 522273
Date Entered .... > 1/21/2014 1:14:21 PM
Date Started .... > 2/5/2014 11:11:38 AM
Date Completed ...... > 2/5/2014 11:23:51 AM
Status .... > Successful
Subbasins .... > 07010207

USGSAutoEmailer@usgs.gov

Interstate Editing Issues

- State Administrative Stewards and POCs receive notification from the NHD Stewardship checkout system any time a subbasin in their 'Area of Interest' is checked out. Checkouts can sometimes be by another state which shares the subbasin. The understanding is that states only edit on their side of the border. If there is a QC issue that needs to be fixed across the border in order for this subbasin to be edited correctly, then that trans-border fix should be checked with the relevant state steward. Occasionally a border edit can have repercussions or unintended consequences.
- Consultation on delineation issues that affect two states (e.g., the delineation and endpoints of Lake Pepin, which Minnesota and Wisconsin consulted on) is encouraged by USGS.
- Knowing what border states are planning to edit ahead of time would be useful. If a subbasin is checkout out for editing by another state, we cannot edit it until they check it back in. To date we do not have a good way to do this. This has not been an issue in the past, but may become so with a more active editing environment in the state.

US-Canada Editing Issues (Harmonizing the U.S. National Hydrography Dataset with Canada's National Hydrography Network (NHN)

There are special issues involved when we are editing in subbasins that Minnesota shares with Canada:

- The US and Canada both have "Bi-National Editing Teams" responsible for border edits and seaming the two data sets together.

- Full HUC-8's are available for all watersheds that span the US-Canada border.

- There is a "seam" along the border such that all features are split at the border. US NHD is seamed with Canada's NHN by Canada's bi-national editing team so that Canada has complete "CAN4" watersheds in NHN. Canada's NHN is seamed with US NHD by NHD's Bi-national editing team so that US has complete subbasins in NHD.

- The "seam" works as follows:
    - Border lakes would have at least two polygons – one on each side of the border. We do have to agree on where the lake (if on a river system) begins and ends, and what it is called.
    - Rivers crossing the border would be split at the border. Names should match across the border.
    - Rivers delineated as 2-dimensional area features that form the border, and their 1-dimensional flowline features (e.g., the Rainy River) are a special case that the Bi-national Editing Teams team would deal with.

- US Stewards can still check out shared subbasins along the border for editing.

- US Stewards could edit on the US side of the border only, and could not edit any features in Canada. Consultation and coordination is encouraged if questions arise.

- There would be a 200-meter buffer along the border that would be "locked" to editing by US stewards. That "lock" is not physical at this point, but USGS may try to enforce something. Right now we just need to agree not to edit those features.
  - An exception to that rule might be that US state Stewards could change or add GNIS names within the buffer (on our side only, of course, and only if they match Canada's name).

- If there are changes that the state stewards feel are necessary within the 200-meter buffer, US stewards would have to let the NHD Bi-National Editing team know.

- How often the two data sets would be "harmonized" is unknown, and is a resource issue.

Managing Geographic Names

- Editing Names in the NHD Update Process – Current USGS Procedure:
  - NHD updaters cannot add a name onto an NHD feature if it is not already in GNIS. If a change is not in GNIS (sometimes as easy as a misspelling) –it is not possible to add it. However – if the incorrect feature is named and the name is in GNIS then we can correct it (by dropping the name from the incorrect feature and adding it to the correct feature).
  - GNIS and NHD currently are still two separate databases. Names have to be added to GNIS. Then names available in GNIS can be added to NHD.
  - In the future NHD and GNIS will be more closely linked.
  - Some rules of thumb:
    - If you are editing and see an unnamed NHD feature and the name is in GNIS – you can just add the GNIS name to the feature.
    - If you are editing and see a GNIS name applied to the wrong feature – as long as the name is in GNIS you can just drop the name from the incorrect feature and add it to the correct feature.
    - You can report the incorrect location to GNIS (with adequate documentation) and GNIS staff will make the location change on the GNIS database.
    - If you believe that a named feature is listed with an incorrect name and the correct name is not in GNIS – then you might have to go through GNIS and probably the state naming authority to resolve it.
    - If you want to add a name (known to the community but not in GNIS) then you need to go through GNIS and the state naming authority to add it.
- Editing Names in the NHD Update Process- Future USGS Procedure:
  - USGS will be adding the ability to add a name to an NHD feature before it becomes official in GNIS. That name will be flagged as "provisional" in the NHD until such a time as the name is officially recognized in GNIS. Then the "provisional" flag will be dropped.
  - In order to move that name from "provisional" to "official" status, you will still need

to follow the authorized state naming process.

- The NHD Update Tool v. 6.2.0 for ArcGIS 10.2.1 is in development over the summer 2014. This version will introduce the "Provisional Names" functionality for the first time. From the ***NHD Newsletter (May 2014)***: "Introducing Provisional Names functionality will allow NHD editors to add new GNIS (GAZ) names while editing the NHD spatial data. The name proposals will be accepted for load into the NHD operational database with a temporary ID. The names will then be reviewed at a later date and, if accepted, the Provisional status will be dropped and the official GAZ Name and GAZ-ID will be made available from the NHD distribution database." (Since Minnesota DNR is the state names authority, the "names review" mentioned in the newsletter article would have to refer back to naming officially submitted by DNR through the formal Board of Geographic Names process.

- The Minnesota GNIS Naming Process:
  - GNIS is maintained by USGS but its content is authorized through the U.S. Board of Geographic Names (http://geonames.usgs.gov/index.html).
  - The US Board of Geographic Names has procedures in place to consider and review new names. This involved working with the recognized state naming authority in each state. Each state may have its own process.
  - The Minnesota Department of Natural Resources – Division of Waters and Ecological Services is the designated Minnesota names authority for naming hydrographic features. Naming lakes, rivers, streams or other natural geographic features in Minnesota is guided by the statutory process found in Minnesota Statute 83A.04 - 83A.07. The state process is outlined on the DNR website.

    This process states that name add or change requests come to the DNR naming authority from the county board level. Documentation for the name addition or change must be provided, and that documentation is passed to the US Board of Geographic Names. Pete Boulay is the main DNR contact for Geographic Names.

    "Naming lakes, rivers, streams or other natural geographic features in Minnesota is guided by the statutory process found in Minnesota Statute 83A.04 - 83A.07. The process requires 15 or more registered voters to petition the county board of commissioners in the county where the feature is located for a public hearing concerning a proposed name. If the county board agrees on a name, the board adopts a resolution in support of the proposed name (or other name if favored by the board as a result of testimony at the hearing), and forwards it to the state commissioner of natural resources (DNR). The name proposed in the resolution MUST be approved by the commissioner of natural resources to become the official name of the feature in Minnesota. Approved names are subsequently submitted to the United States Board on Geographic Names for federal approval and use." (Source: http://www.dnr.state.mn.us/waters/surfacewater_section/hydrographics/naming_features.html)

NHD-WBD Stewardship

- WBD also needs an official state steward to work with the USGS-NRCS WBD Team.
- WBD currently has no signed stewardship agreement in Minnesota, but there is an active watershed delineation program at the state level.
    - The Minnesota Department of Natural Resources (Division of Waters and Ecological Services) is recognized as the watershed boundary authority in Minnesota
    - DNR maintains a "Catchments" data layer (DNR Watersheds - DNR Level 08 - All Catchments) - which is a very fine level of watershed delineation, which has been used to derive the larger watershed units of the WBD (e.g., HUC -2, HUC-4, HUC-6, HUC-8, HUC-10, and HUC-12).
    - Minnesota's WBD was aggregated from the DNR Catchments and attributed according to WBD rules, then seamed by USGS/NRCS with WBD for surrounding states.
    - DNR has actively worked with the WBD Team to consult on watershed boundary seaming along the US-Canada border for the US-Canada Hydrography Data Harmonization effort.
    - There will be future updates to the DNR Catchments delineations which will need to be submitted to become WBD updates.
    - The exact process by which future updates to the DNR Catchments layer are submitted as WBD updates is discussed in *Chapter 10.*
- Because of its role in in state watershed mapping, DNR has served as the unofficial, acting steward of the WBD, but without a signed stewardship agreement or funding to support the additional activities that responsibility to the WBD entails.
- The State Administrative Steward for NHD and the State Steward for WBD do not have to be the same organization.
- Nonetheless, any NHD editors need to recognize the watershed boundary knowledge and authority that rests with the DNR. Any NHD editing that suggests the need for HUC boundaries changes needs to consult with DNR on those potential changes.

Past State NHD Editing History

MnGeo has provided the Minnesota principal stewardship and some NHD editing functions in the past, but without consistent funding or the official state recognition that a signed stewardship agreement would confer. MnGeo has routinely participated on the NHDAdvisory Team, and has functioned as the primary point of contract for USGS NHD questions to the state. Answering those questions often involved consulting with other state agencies.

As a primary NHD user in Minnesota and historically active NHD developer, the Minnesota Pollution Control Agency has played a very active role in NHD policies and processes, is a member of the NHD Advisory Team, and also a member of the NHD Management Team – a smaller group that directs overall policy for NHD Development.

Past NHD editing activity has been performed by MnGeo and Metropolitan Council, often funded through one-time grants.

At present (2014), the MPCA and USFS have registered as editors, have taken NHD Update Tool training, and are poised to begin editing the NHD.

On USGS editing: Historically USGS editors have fixed names or branched reaches, performed "maintenance lite" – a list of QC steps and fixes, migrated reaches based on a new version of the watershed containers (WBD), editing for map photo-revision, and, recently, is performing a "network improvement project" – designed to make the high-resolution data NHDPlus-ready.

- Often USGS asks the State Administrative Steward if they want to do the fix (or has a problem with USGS doing it). If the state is not in the position to do the work then USGS will do it.
- If as a state we want minimal work by USGS on the NHD (to avoid potential conflicts with state and state-derived layers), then the state needs to be able to step up and do those edits (e.g., a consistent, stronger state stewardship capability).

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[i] The terms "State Administrative Steward" and "Principal Steward", for purposes of this report, are interchangeable.

[ii] Prior to the April 2012 Release of the NHD Update Tool v.4.0.0, previous versions of the desktop NHD editing tool were called "NHDGeoEdit". The new name was applied with the first release of the tool that was based on a replicate checkout from the NHD. The previous versions, the "NHDGeoEdit" tools, used a Status Table to track edits and an XML file to post updates back to the national NHD database.

[iii] The terms "subbasin" and "HUC-8" are interchangeable.

Appendix 8: DNR Event-Referencing Strategies

- related to *Chapter 8: Events and Event Maintenance*

Objective

To test DNR event-referencing strategies as outlined in **Chapter 6: Maintenance Options**. *Strategies are:*

Option 1: Core DNR feature classes (for streams and **open water** only) are referenced as **events** to **NHD** and exported to replicate current DNR core layers. Other DNR data is referenced to these core feature classes

Option 2: DNR Data is referenced as events directly on NHD. Derived products are generated using new processes (to be developed).

Option 3: DNR data is referenced to core feature classes within the **DNR Hydrography** (Enterprise) **Dataset** and exported as derived products using existing processes.
(*Note:* This is the current condition.)

Summary

- Two essential DNR core base layers (representing streams and open water features) can be successfully derived from NHD datasets (Option 1). This option allows DNR to continue using existing processes to create derived products without significant changes in operation.

- DNR's core and derived product layers (representing streams and open water features) can be successfully derived from events referenced directly to the NHD dataset (Option 2). This option requires that DNR develop new processes for generating derived products directly from NHD.

- *Hydrologic Points of Interest (HPOI)* can be maintained as point events on the DNR streams core feature class (Options 1 & 3) and directly referenced to NHD flowlines (Option 2).

- Under all options, DNR retains control of its event data (i.e., it is not stored directly in NHD).

- DNR Hydrography core feature classes representing Public Waters Basins, National Wetlands Inventory and DNR Catchments cannot be derived from any NHD feature class and will need to be maintained separately by DNR (Options 1, 2 & 3).

- Options 1 & 2 result in a single, statewide hydrography dataset for streams and open water only.

Procedural Details & Analysis

Referencing DNR data as events on NHD hydrography layers is a necessary condition for *Maintenance Options 1 and 2* (*Chapter 6*). To fully meet DNR business needs, each option must result in derived GIS products that match those currently being produced. Furthermore, DNR must retain control of DNR data storage and maintenance.

The DNR event-referencing strategies for *Maintenance Options 1 and 2* were tested and the results appear below. Option 3 describes the current condition and is included first for comparison purposes.

Important note: <u>All options require that the DNR Hydrography and NHD datasets have been fully synchronized prior to implementation</u> (*Chapter 4*).

Option 3: DNR Hydrography Dataset (current condition)

Currently, DNR uses the DNR Hydrography (Enterprise) Dataset to meet its business needs for geospatial hydrography data (*Chapter 1*). Hydrography-based derived product layers for the GDRS and Minnesota Geospatial Commons are referenced to the core feature classes (i.e., *Stream Routes with Kittle Numbers and Mile Measures, DNR Open Water Features and Public Waters Basins)* derived from this master dataset. How DNR derived product data is handled for each feature class is described below.

Process Overview

Streams: DNR maintains an individual linear event table for each stream-derived product layer (e.g., designated trout streams, stream types, stream order, etc.) Linear events are referenced to the core streams layer using Kittle Numbers and mile measures. Referenced events are exported as new derived product feature classes in individual geodatabases to the GDRS and Minnesota Geospatial Commons.

Lakes and Open Water: Open Water basin-derived product layers (e.g., designated trout lakes, walleye rearing ponds, stocked waterbodies, etc.) are not referenced as events, but rather listed in individual attribute tables by Lake ID (i.e., DOWLKNUM). These tables are joined to the core Open Water feature class and specific features are selected via attribute queries. Selected features are exported as new derived product feature classes in individual geodatabases to the GDRS and Minnesota Geospatial Commons.

Public Waters Basins: Public Waters basin-derived product layers (e.g., designated wildlife lakes, shallow lakes, wild rice lakes, etc.) are listed in individual attribute tables by Lake ID (i.e., DOWLKNUM). These tables are joined to the core Public Waters basins feature class and specific features are selected via attribute queries. Selected features are exported as new derived product feature classes in individual geodatabases to the GDRS and Minnesota Geospatial Commons.

Wetlands: The new National Wetlands Inventory (i.e., NWI, in progress 2014) is maintained as a separate polygon feature class within the DNR Hydrography Dataset and is not integrated with other feature classes at this time. Future plans are to update or replace many of the core Open Water and/or Public Water features with features from the new NWI dataset.

HPOI features: Hydrologic Points of Interest (HPOI) are stored in event tables and referenced to the core streams layer using Kittle Numbers and mile measures. Referenced events (e.g., catchment pour points, water control structures, dams, etc.) are exported as new derived product feature classes in individual geodatabases to the **GDRS** and **Minnesota Geospatial Commons**.

DNR Catchments: DNR Catchments are maintained in a polygon feature class and are dissolved to create different levels of nested watersheds for the DNR Watershed Suite and WBD.

Option 1: Export NHD to replicate DNR core hydrography layers (streams and open water only)

Under this option, NHD features are exported to match the current DNR core hydrography feature classes for streams and open water. Derived products are generated by referencing event tables to these DNR core feature classes using current processes (refer to Option 3, above).

Process Overview

Streams: DNR Kittle Routes are maintained as linear events referenced to NHD flowlines. These events are exported to a new feature class, projected to UTM NAD83 Zone 15 and converted to routes with mile measures, thus becoming the new DNR core streams layer (i.e., *Streams with Kittle Numbers and Mile Measures)*. All stream-derived event tables are then referenced to this core layer; derived products are generated using current processes.

Open Water: NHD waterbodies are exported as an Open Water basins feature class, projected to UTM NAD83 Zone 15 and joined to a DNR attribute table (i.e., Lakes DB), thus becoming the new DNR core Open Water basins layer (i.e., *DNR Water Features)*. All open water basin-derived tables are then referenced to this core layer; derived products are generated using current processes.

Public Waters Basins: The Public Waters basins feature class must be maintained separately because there is no way to store these OHWL delineations as features in (or events on) the core Open Water layer. All public water basin-derived event tables are referenced to the *Public Water Basins* feature class; derived products are generated using current processes.

Wetlands: The new National Wetlands Inventory (i.e., NWI, in progress 2014) is maintained as a separate polygon feature class within the DNR Hydrography Dataset and is not integrated with other feature classes at this time. Currently, it is not possible to derive NWI from other NHD or DNR feature classes.

HPOI features: Hydrologic Points of Interest (HPOI) are stored in event tables and referenced to the core streams layer; derived products are generated using current processes.

DNR Catchments: DNR Catchments are maintained in a separate polygon feature class. While they are dissolved to create different levels of nested watersheds for WBD, there is no comparable HUC-level feature class within WBD to hold these small-scale features.

Methods used for testing Option #1

Testing was performed to ensure that core hydrography feature classes (for streams and open water only) could be generated from DNR event data referenced to NHD. The general methods are described below; ***tool names appear in bold italics.***

- The following NHD feature classes were exported from the MN reconciled NHD dataset (default SDE version): NHD flowlines, NHD waterbodies, NHD 2-D areas (river polygons) and WBD watersheds (HUC's 04-12).

Streams

- The core stream routes feature class *(i.e., Stream Routes with Kittle Numbers and Mile Measures)* was referenced to NHD Flowlines in ArcMap.
    - ***ArcToolbox: Linear Referencing Tools: Locate Features Along Routes*.**
      This tool references an existing feature class along another route feature class and writes the route and measure information to a new event table. (Because the features of the DNR and NHD datasets will be identical due to prior synchronization (*Chapter 4*), this should be a simple operation.)
- The resulting event table was displayed as linear event features along NHD flowlines
    - ***File: Add Data: Add Route Features*** *OR*
    - ***ArcToolbox: Linear Referencing Tools: Make Route Event Layer***
- Event data was exported as a new route feature class
    - ***Data: Export Data***
- Data was projected to UTM NAD83 Zone 15
    - ***ArcToolbox: Data Management Tools: Projections and Transformations: Feature: Project***
- The [LENGTH_MI] field was re-calculated with mile measures
    - ***Calculate Geometry: Length (miles)***
- The data was converted to a new route feature class
    - ***ArcToolbox: Linear Referencing Tools: Create Routes*** *using [LENGTH_MI] as the measure field*

Open Water Basins

- The Permanent IDs of Open Water polygon features were stored in a stand-alone table along with other DNR-specific attributes; this table was joined to the NHD Waterbody feature class.
- Features were exported as the new Open Water (*DNR Water Features)* layer
    - ***Data: Export Data***
- Data was projected to UTM NAD83 Zone 15
    - ***ArcToolbox: Data Management Tools: Projections and Transformations: Feature: Project***
- Unnecessary attributes were dropped
    - ***ArcToolbox: Data Management: Field: Delete Field***

Conclusions for Option #1

- Testing demonstrated that the two essential DNR core base layers (i.e*., Stream Routes with Kittle Numbers and Mile Measures* and *DNR Water Features*) can be successfully derived from the reconciled MN version of NHD (in SDE).

- This option allows DNR to continue using existing processes to create derived stream/open water/HPOI products from the core layers without significant changes in operation. DNR retains control of DNR data and its derived products in-house, with as little interruption to current processes as possible.

- *Hydrologic Points of Interest (HPOI)* can be maintained as point events for reference to *Stream Routes with Kittle Numbers and Mile Measures.*

- DNR retains control of its event data (i.e., it is not stored directly in NHD).

- The following core DNR Hydrography feature classes will need to be maintained separately by DNR as they cannot be derived from any NHD feature class: *Public Waters Basins, National Wetlands Inventory* and *DNR Catchments.*

- This option results in a single, statewide hydrography dataset (for streams and open water only) that meets the business needs of DNR.

Option 2: DNR hydrography data is referenced directly to NHD base feature classes as events

Under this option, DNR core and derived data are referenced directly to NHD feature classes within the MN NHD state dataset. New processes must be developed to automate the generation of derived products from NHD to the GDRS and Minnesota Geospatial Commons.

Process Overview

Streams: All stream-derived layers are referenced to NHD flowlines as linear events, joined to additional attributes if necessary, and exported as derived products.

Open Water Basins: Open Water-derived layers are referenced as polygon events to the NHD waterbody feature class, joined to additional attributes if necessary, and exported as derived products.

Public Waters Basins: The Public Waters basins core feature class must be maintained separately because there is no way to maintain these OHWL delineations as features in (or events on) the NHD waterbodies layer. All public water basin-derived event tables are referenced to the *Public Water Basins* feature class; derived products are generated using current processes.

Wetlands: The new National Wetlands Inventory (i.e., NWI, in progress 2014) is maintained as a separate polygon feature class within the DNR Hydrography Dataset and is not integrated with other feature classes at this time. Currently, it is not possible to derive NWI from other NHD or DNR feature classes.

HPOI features: Point features can be referenced to the NHD flowlines as point events.

DNR Catchments: DNR Catchments are maintained in a separate polygon feature class. While they are dissolved to create different levels of nested watersheds for WBD, there is no comparable HUC-level feature class within WBD to hold these small-scale features.

Methods used for testing Option #2

Testing was performed to ensure that all core and derived hydrography feature classes (for streams and open water only) could be generated from DNR event data referenced directly to NHD. The general methods are described below; ***tool names appear in bold italics.***

- The following NHD feature classes were accessed from the MN NHD dataset via the GDRS: NHD flowlines, NHD waterbodies, NHD 2-D areas (river polygons) and WBD watersheds (HUC's 04-12).

Streams

- An existing derived product layer *(i.e., Major River Centerlines)* was referenced to NHD Flowlines
  - ***ArcToolbox: Linear Referencing Tools: Locate Features Along Routes*****.**
    This tool references an existing feature class along another route feature class and writes the route and measure information to a new event table. (Because the features of the DNR and NHD datasets will be identical due to prior synchronization (*Chapter 4*), this should be a simple action.)
  - Resulting events had associated NHD Reach Codes and % measures in addition to DNR Kittle Numbers, mile measures and event-specific attributes.
- Referenced events were exported as a line feature class
  - ***Data: Export Data***
- Data was projected to UTM NAD83 Zone 15
  - ***ArcToolbox: Data Management Tools: Projections and Transformations: Feature: Project***
- Unnecessary attributes were dropped
  - ***ArcToolbox: Data Management: Field: Delete Field***

Open Water Basins

- An existing open water-derived layer (i.e., *Designated Trout Lakes*) was referenced to NHD using the ***USGS Hydrologic Event Management (HEM) tool***
  - Polygon events were referenced directly to NHD waterbodies as partial or full polygons (*Note:* the event must be equal in size or smaller than the corresponding NHD waterbody)
  - Resulting events have associated NHD Permanent IDs
  - A separate table of additional DNR-specific attributes was joined to the events
- Referenced events were exported as a polygon feature class
  - ***Data: Export Data***
- Data was projected to UTM NAD83 Zone 15
  - ***ArcToolbox: Data Management Tools: Projections and Transformations: Feature: Project***
- Unnecessary attributes were dropped
  - ***ArcToolbox: Data Management: Field: Delete Field***

Conclusions for Option #2 (*denotes same conclusion as for Option #1)

- Testing demonstrated that DNR's core <u>and</u> derived product stream and open water layers <u>can</u> be successfully derived from events referenced <u>directly to the NHD</u> dataset.
- This option requires that DNR develop <u>new processes</u> for generating derived products directly from NHD.
- *Hydrologic Points of Interest (HPOI)* can be maintained as point events for reference to *NHD* flowlines.
- DNR retains control of its event data (i.e., it is not stored directly in NHD).*
- The following core DNR Hydrography feature classes will need to be maintained separately by DNR as they <u>cannot be derived</u> from any NHD feature class: *Public Waters Basins, National Wetlands Inventory* and *DNR Catchments.**
- There will be an initial large effort necessary to create event feature classes for each of the 40+ DNR derived product layers representing streams and open water.
    - Standard tools (i.e., ***ArcToolbox: Locate Features Along Routes***) and/or custom tools (i.e., ***USGS HEM tools: Import Features***) can be used for initial event creation.
    - Standard tools (i.e., ***Linear Referencing)*** and/or custom tools (i.e., ***HEM tools***) can be used to maintain (i.e., add, delete, migrate, move) events in response to future feature edits.
- This option allows users to display DNR data on the NHD framework while taking advantage of NHD-compatible analysis tools, such as upstream tracing on the NHD flowline network.
- This option results in a single, statewide hydrography dataset (for streams and open water only) that meets the business needs of DNR. *

DNR Event Management

DNR event management is described in **Chapter 8: Events and Event Maintenance** (see headings: *DNR Event Creation Process*; *DNR Event Maintenance Process).*

DNR currently uses standard ArcMap and ***ArcToolbox: Linear Referencing tools*** to maintain stream-derived data in event tables for referencing on the core streams hydrography feature class (i.e., *Stream Routes with Kittle Numbers and Mile Measures)*. Choosing Option #1 or #3 would continue this practice.

If Option #2 is chosen, DNR would instead reference all core and derived data for streams and open water directly to NHD. If so, DNR would be able to ***use USGS Hydrography Event Management (HEM) tools*** to reference and maintain events on NHD. Conclusions from internal DNR testing with HEM tools are below.

Conclusions from HEM Tool Testing on DNR Event Data

- NHD HEM tools are easy to use for creating and maintaining DNR events on NHD feature classes
    - HEM tools offer the ability to reference full or partial polygon events to NHD waterbodies, as long as they are smaller than or equal in size to the underlying waterbody polygon
    - Public Waters Basins polygon events cannot be referenced to NHD waterbodies because they are larger than the Open Water delineations used to create the NHD waterbodies
- An ***HEM IMPORT*** process is available to import existing DNR features to NHD events
    - DNR has 40+ data layers that would need an initial import and referencing to NHD
    - The DNR_HYDRO_ID could be specified as a LINK_ID during ***IMPORT*** to populate the *Feature_ClassRef* field
        - *Note:* this ID must first be converted to text prior to ***IMPORT***
        - Imported ID values could then be calculated into the *Feature_Permanent_ID* field to be used for joining additional attributes from DNR tables
    - *EventType* (Long int) could be populated during import to group events of the same type (e.g., assign Public Watercourses = type 1, Trout Streams = type 2, etc.)
- Selecting multiple features for multiple linear events is easy; attributes can be mass- populated
    - *Source_Originator*, *Source_DataDesc* and *EventType* are useful attribute fields for recording DNR-specific information
    - New attribute fields CANNOT be added to NHD feature classes
    - Additional fields CAN be added to event tables and edited while adding/editing events
    - External tables CAN be joined to event tables via the *Feature_Permanent_ID* (text)
    - ***HEM Create/Edit Line*** event tools DON'T WORK when an external table is joined to an NHD feature class
        - A DNR attribute table can be joined for purposes of editing (outside of the HEM tool) and/or to add attributes prior to exporting derived products
        - *Relating* the attribute table DOES WORK when creating and editing line events. The related table may be opened and edited alongside the line event attribute table.

- Events that change due to geometry changes can be identified using the ***HEM Synchronize Events*** command; (note that changes are based on the feature edit date).

- DNR linear events can be maintained either as 1) "floating" events, which move along the stream linear features as geometry changes, or 2) as "fixed" events that exist as derived features in a feature class.

  - If floating events are referenced to the state NHD on the GDRS, they will "move" when the GDRS dataset is updated. If derived products are automated daily from floating events, then these events must be "migrated" as soon as the edited features are available on the GDRS; otherwise, they will be displayed in the wrong locations.
  - If derived products are not automated from floating events, then migration can occur as time allows; however, there will be a temporary lack of synchronicity between the new GDRS NHD and the existing GDRS derived products.
  - If "fixed" events are used, there will also be a temporary lack of synchronicity between the new GDRS NHD and the existing GDRS derived products until the derived products can be updated.
  - DNR is likely to maintain data as "floating" events on NHD but <u>control the automation of derived products</u> to the GDRS (until events can be updated); thus, some temporary lack of synchronicity between NHD and derived layers will be tolerated.
  - Users of their own "floating event" data on NHD must be mindful of changes to underlying geometry, as events will need to be periodically migrated to remain valid..
  - Layers that involve many or all streams of the state (e.g., kittle routes or stream types) will be affected by almost any geometry change, thus making event updates frequent.

- An effective *Change Detection/Notification/Review/Reconciliation* process will be essential to retaining the integrity of DNR derived products. In addition to the strategies outlined in Maintenance Options 1-3 (*Chapter 6*), suggestions include:

  - Limiting the number of partners that can directly edit the NHD Dataset
  - Use attributes to improve the maintenance of DNR events (e.g., add an attribute that indicates whether the entire stream is affected or whether a measure has a "fixed" location)
  - Maintain backup copies of DNR event layers as background reference layers when editing NHD; they may be useful if you need to revert back to a previous shape
  - DNR Event tables should be maintained at DNR and not be incorporated into the state or federal NHD Datasets; this provides more control for DNR over its data, attributes and derived products.

References

Chapter 1: DNR Hydrography Dataset Overview

Chapter 4: NHD-DNR Dataset Synchronization

Chapter 6: Maintenance Options

Chapter 8: Events and Event Maintenance

Glossary

*Note: **BOLD** items within descriptions below also have definitions in this Glossary.*

24K: Shorthand for 1:24,000 scale. In this document, used when referring to original **DNR** hydrographic data whose features were based on USGS 1:24,000 scale topographic maps (e.g., DNR 24K Streams, DNR 24K Lakes).

ArcGIS Online (AGOL): ESRI technology that allows the creation of interactive web maps and applications for sharing via desktops, browsers, smartphones and tablets. *(http://www.esri.com/software/arcgis/arcgisonline.html)*

ArcGIS Spatial Database Engine (SDE): ESRI technology to manage geospatial data in a relational database management system (RDBMS) accessible by ArcGIS clients. SDE provides the framework to facilitate the versioned editing environment in multiuser geodatabases (i.e., supports multi-editors to a single centralized geodatabase). *(http://www.esri.com/software/arcgis/arcsde.html)*

Conflation: Refers to the process of substituting one dataset's geospatial features (e.g., **NHD**) with another's corresponding features (e.g., **DNR**) while retaining the original features' attributes (e.g., NHD). Attributes of one dataset are transferred to the corresponding features of another dataset, while retaining the database structure of the original. (See *Chapters 4 and 5*.)

Data Governance: Developing and integrating the processes, policies, standards, organization, and technologies required to leverage data as an enterprise asset. (Data Governance Winter Conference, Fort Lauderdale, FL, November 2013)http://www.debtechint.com/dgwinter2013/.

Designated Trout Lakes: Refers to lakes inhabited by trout species other than lake trout and designated by the (MN**DNR**) commissioner as trout lakes. These lakes have special restrictions in order to protect and foster the propagation of trout. Designated trout lakes are listed by County, Township, Range and Section in *Minnesota Rules 6264.0050 Designated Trout Lakes and Streams.*

Designated Trout Streams: Refers to natural and altered watercourses designated by the (MN**DNR**) commissioner as trout streams. These watercourses have special restrictions in order to protect and foster the propagation of trout. Designated trout streams and their tributaries are listed by County, Township, Range and Section in *Minnesota Rules 6264.0050 Designated Trout Lakes and Streams*.

DLG (USGS Digital Line Graph 100K) Data: Digital Line Graphs (DLGs) are digital vector representations of cartographic information derived from USGS maps and related sources. DLG data features were derived at multiple scales (e.g., 20K, 24K, 25K and 100K). The 100K DLG hydrography data was an early source of the DNR Hydrography Dataset Open Water feature class. (https://lta.cr.usgs.gov/DLGs)

DNR: See definition below for **Minnesota Department of Natural Resources (MNDNR)**.

DNR Catchments: See definition below for **DNR Level 08 Catchments**.

DNR Hydrography Dataset: Refers to the Minnesota **DNR**'s single, authoritative (enterprise) statewide dataset of geospatial **hydrography** data layers built to meet the business needs of DNR and the wider GIS community. It contains core feature classes representing surficial hydrography features including streams, open water basins, public water basins, wetlands, watersheds and hydrologic points of interest. *(See Chapter 1: **DNR** Hydrography Dataset Overview)*

DNR Level 04 Watersheds - DNR Majors: **DNR** Level 04 watersheds derived from **DNR Level 08 Catchments**. They are geographically equivalent to the **WBD** Level 04 HUC-8 watersheds. DNR Major Watersheds have one or two-digit identifiers (e.g., Lake Superior-North, DNR Major 1) ranging from # 1-81 (*Note: #'s 6, 45 and 64 are not used.*) (Vaughn, Sean. *DNR Watershed Delineation Project: History, Methodology Terminology & Data Attribution.MNiT Services @ MN Dept. of Natural Resources, 2014)*

DNR Level 08 Catchments: DNR Catchments are the smallest manually delineated drainage areas mapped by the **DNR Watershed Delineation Project (DNR-WDP).** Each catchment contains all land area(s), as well as non-contributing inclusions and water features, upstream from, or between Hydrologic Points of Interest (HPOI) defining other DNR Catchments. DNR Catchments are “chained” through their upstream attributes to define the entire upstream contributing area (watershed) for individual pour points. DNR Catchment polygons are dissolved to create different levels of nested watersheds for the DNR Watershed Suite and the USGS Watershed Boundary Dataset (WBD). **Note:** there is no geographically-equivalent hydrologic unit within WBD that is equivalent to DNR Catchments. (Vaughn, Sean. *DNR Watershed Delineation Project: History, Methodology Terminology & Data Attribution.MNiT Services @ MN Dept. of Natural Resources, 2014)*

DNR Watershed Delineation Project (DNR-WDP): This project was created to meet a 1998 legislative mandate to delineate watershed boundaries for lakes greater than 100 acres in size using GIS technology. Since its inception, this mapping initiative has mapped over 11,000 DNR Catchments for water resource management, decision making and hydrologic modeling in Minnesota. (Vaughn, Sean. *DNR Watershed Delineation Project: History, Methodology Terminology & Data Attribution.MNiT Services @ MN Dept. of Natural Resources, 2014)*

Dynamic Segmentation: The ARcGIS process of computing and displaying the mapped locations of **events** stored and managed in an event table using a **linear referencing** measurement system. The term dynamic segmentation is derived from the concept that line features need not be split (in other words, "segmented") each time an attribute value changes; you can "dynamically" locate the segment. *(Adapted from ArcGIS 10.2 help reference)*

Event: A linear, continuous or point feature that is referenced (i.e., indexed) along a measured **route** feature in the same way that a house is referenced to a street address. *(Adapted from ArcGIS 10.2 help reference)*

Fisheries Lake Survey Database: DNR’s authoritative (Oracle) database regarding Minnesota lakes that have been surveyed at least once by DNR Fisheries. Attributes include DNR Lake ID (i.e., DOWLKNUM) and official lake name from DNR **Lakes DB**. Additional attributes include county, acreage, watershed, fisheries management office and Schupp Lake Class. *(See Chapter 1: **DNR** Hydrography Dataset Overview)*

Geospatial Data Resource Site (GDRS): A set of statewide ArcGIS data layers, tools and metadata built by the **DNR** and shared by Minnesota agencies for the distribution of geospatial data. *(Adapted from https://www.assembla.com/spaces/geospatial-data-resource-site/wiki)*

GNIS (Geographic Names Information System): Online database of official names, identifiers and other information regarding US geographic features maintained by the USGS. *(http://NHD.usgs.gov/gnis.html)*

Group 1 (non-lake connector): A category of digitized stream lines in both **DNR** and **NHD** hydrographic data that represent "interpreted", non-visible water flowage patterns on the land (e.g., water flow through a swamp). This category, along with the others, was used in feature comparison analysis to quantify differences between the NHD and **DNR Hydrography** datasets. *(See Chapter 3)*

Group 5 (lake connector): A category of digitized stream lines in both **DNR** and **NHD** hydrographic data that represent "interpreted", non-visible water flowage patterns through lakes and ponds. This category, along with the others, was used in feature comparison analysis to quantify differences between the NHD and **DNR Hydrography** datasets. (*See Chapter 3*)

Hydrologic Unit (HUC): Defined by the USGS **Watershed Boundary Dataset (WBD)** as a "drainage area delineated to nest within a multi-level, hierarchical drainage system. Its boundaries are defined by hydrographic and topographic criteria that delineate an area of land upstream from a specific point on a river, stream or similar surface waters." Each HUC is assigned a unique number identifier (i.e., Hydrologic Unit Code - HUC) whose length corresponds to the level (e.g., Level 01 = two-digit HUC; Level 02 = four-digit HUC; Level 03 = six-digit HUC; Level 04 = eight-digit HUC, etc.) Level 06 (i.e., twelve-digit HUC) is currently the smallest watershed unit available at the national level. (http://NHD.usgs.gov/wbd.html)

Hydrologic Unit (DNR): The federal Watershed Boundary Dataset defines a set of nested 'Hydrologic Units' at several levels, defined as HUC02, 04, etc. The DNR definition is more generic, i.e., a 'hydrologic unit' is a drainage area unit that can be of any size. DNR Catchments are generic hydrologic units. As with 'watersheds', a classic hydrologic unit is defined when all drainage area within the unit converges on a point. (adapted from Vaughn, Sean. *DNR Watershed Delineation Project: History, Methodology Terminology & Data Attribution.MNiT Services @ MN Dept. of Natural Resources, 2014, p.87)*

HUC-8: Refers to a USGS WBD Level 04 **Hydrologic Unit (HUC)** having an 8-digit HUC code (e.g., 04010600). HUC-8s are geographically equivalent to **DNR Level 04 Watersheds - DNR Majors.**

Hydrography: A branch of applied sciences which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers. *(http://en.wikipedia.org/wiki/Hydrography)* In this document, it refers to geospatial data, both digital and hardcopy, of Minnesota's surface water system, including stream, lake, watershed and other point (e.g., gages) and linear (e.g., dams) features.

Identity: An ArcGIS geoprocessing operation that computes a geometric intersection of the so-called *input* and *identity* features. The input features or portions thereof that overlap identity features will get the attributes of those identity features. *(Adapted from ArcGIS 10.2 help reference)*

Lakes DB (DNR): DNR's authoritative database for data regarding Minnesota's Public Water basins and wetlands, including attributes for DNR Lake IDs (i.e., DOWLKNUM), official Public Water basin names, Circular 39 wetland types, PW classifications and current and historic water levels.

LiDAR: Commonly used as an acronym for Light Detection and Ranging, LiDAR is a remote sensing technology that measures distance by illuminating a target with laser and analyzing the reflected light. (*http://en.wikipedia.org/wiki/Lidar*)

Linear Referencing: The ArcGIS method of storing geographic locations by using relative positions along a measured linear feature or **route**. For this project, linear referencing refers to designating the percent upstream along a given stream **reach** that associated point (e.g., gage: 25%) or linear (e.g., impaired portion of stream: 10% to 78%) **events** reside. See also **Dynamic Segmentation.** *(Adapted from ArcGIS 10.2 help reference)*

Minnesota Department of Natural Resources (MNDNR or DNR): A Minnesota state agency responsible for managing the state's natural resources to provide outdoor recreation opportunities and commercial uses of natural resources in a way that creates a sustainable quality of life. *(Adapted from http://www.DNR.state.mn.us/index.html)*

Minnesota Geospatial Commons: A collaborative place (i.e., web portal) for users and publishers of geospatial resources in Minnesota. (*http://gisdata.mn.gov/*)

Minnesota Geospatial Information Office (MnGeo): A state agency that coordinates the development, implementation, support and use of geospatial technology within Minnesota. They are advised by advisory councils, committees and workgroups representing stakeholders within state government and around the state. *(Adapted from http://www.mngeo.state.mn.us/index.html)*

MNDOT Basemap Data: The GIS Basemap is a planning-level set of data developed by the Minnesota Department of Transportation (MNDOT) at a scale of 1:24,000. The dataset includes information about transportation features, boundaries, state lands, and stream and lake locations. 1980's vintage Basemap data served as early GIS layers for Minnesota's hydrography and transportation needs. (http://www.dot.state.mn.us/maps/gdma/gis-data.html).

MPARS: An acronym for the **MNDNR Permitting and Reporting System**, this online web application is used for water use reporting, permit applications and permit change requests. The **DNR Hydrography Dataset** provides background layers for this online application. (*http://www.dnr.state.mn.us/mpars/index.html)*

Multi-ring buffering: An ArcGIS geoprocessing operation that creates multiple buffers at specified distances around input features. These buffers can optionally be merged and dissolved using the buffer distance values to create concentric, non-overlapping buffers. See also *Chapter 3*. *(Adapted from ArcGIS 10.2 help reference)*

National Hydrography Dataset (NHD): A national geospatial dataset that represents surface water drainage features such as rivers, streams, canals, lakes, ponds, coastline, dams and stream gages. *(Adapted from http://NHD.usgs.gov/)*

NHDArea: NHD features that constitute areal hydrographic landmarks such as a stream whose width requires more than a single line to delineate it. (*Adapted from http://NHD.usgs.gov/userguide.html?url=NHD_User_Guide/Feature_Catalog/NHD_Feature_Catalog.htm)*

NHDFlowline: **NHD** features consisting of measured **route** features that represent the linear surface water drainage network. Flowlines have a reach code and a measure, allowing for the establishment of upstream/downstream relationships as well as for analysis and modeling capabilities. (*Adapted from http://NHD.usgs.gov/userguide.html?url=NHD_User_Guide/Feature_Catalog/NHD_Feature_Catalog.htm)*

NHDWaterbody: NHD features that represent area-based hydrographic features such as lakes, ponds and wetlands. Like **NHD**Flowlines, lakes and ponds must have a Reach Code while wetlands may or may not have a Reach Code. (*Adapted from http://NHD.usgs.gov/userguide.html?url=NHD_User_Guide/Feature_Catalog/NHD_Feature_Catalog.htm*)

National Wetlands Inventory (NWI): A nationwide inventory of U.S. wetlands established by the US Fish and Wildlife Service in 1974 to provide its biologists and others with information (including geospatial data) on the distribution of wetlands to aid in wetland conservation efforts. *(Adapted from http://www.fws.gov/wetlands/NWI/index.html)*

Open Water (OW): A waterbody delineation based upon the visible and/or interpreted exposed water component of the basin as identified on aerial photography. This area contains both the deep water (limnetic) and shallow water, vegetated (littoral) zones [i]. These delineations are subject to frequent change based upon fluctuating water levels in any given season. Under ordinary conditions, open water delineations nest completely within and/or share common boundaries with public waters basin delineations. This is the delineation representing the most common perception of a "lake" as found in the **DNR Hydrography Dataset - Open Water** feature class. See *Chapter 1 - DNR Hydrography Dataset*. ([i] Refer to **DNR** Aquatic Basin Zones 1 & 2, pp. 74-75 in *Vaughn, Sean. DNR Watershed Delineation Project: History, Methodology Terminology & Data Attribution.MNiT Services @ MN Dept. of Natural Resources, 2014)*

Ordinary High Water Level (OHWL): An elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial *(Minnesota Statute 103G.005)*. The OHWL is the landward extent of **DNR** jurisdiction over anyone who works in the bed of public waters or public waters wetlands (collectively referred to as **public waters**). *(From http://files.**DNR**.state.mn.us/waters/surfacewater_section/hydrographics/ohwl.pdf)*

Minnesota Pollution Control Agency (MPCA): This state agency monitors environmental quality, offers technical and financial assistance and enforces environmental regulations. They find and clean up spills or leaks that can affect the state's health and environment in addition to developing statewide policy and supporting environmental education. *(Adapted from http://www.pca.state.mn.us/index.php/about-mpca/index.html)*

Public Waters (PW) basin: The delineation of a wetland or waterbody delimited by its **Ordinary High Water Level (OHWL)**. Public Waters (basins, wetlands and watercourses) include 11 categories of waters as defined by *Minnesota Statute 103G.005*. Activites related to human alteration of public waters are regulated by Minnesota **DNR**.

Public Waters (PW) wetland: Defined by *Minnesota Statute 103G.005* as all Type 3 (inland shallow fresh marshes), Type 4 (inland deep fresh marshes) and 5 (inland open fresh water, shallow ponds and reservoirs) wetlands as defined in *United States Fish and Wildlife Service Circular No. 39 (1971)*[ii], not included within the definition of public waters, that are ten or more acres in size in unincorporated areas or 2-1/2 or more acres in incorporated areas. Activites related to human alteration of public waters are regulated by Minnesota **DNR**. See *Appendix 2c*. *([ii] Classification of Wetlands and Deepwater Habitats of the United States, U.S. Fish and Wildlife Service, p.28, 1979, reprinted 1992) - Replaces USFWS Circular 39 (1971)*

Public Waters (PW) watercourse: Defined by *Minnesota Statute 103G.005* as 1) Natural and altered watercourses with a total drainage area greater than two square miles and 2) natural and altered watercourse watercourses designated by the (**DNR**) commissioner as trout streams. Activites related to human alteration of Public Waters watercourses are regulated by Minnesota **DNR**.

Reach: Generally, a continuous portion of surface water with similar hydrologic characteristics. In **NHD**, each reach is assigned a *Reach Code* that uniquely identifies it and is used for referencing tabular events to the **NHD** framework. *(From http://NHD.usgs.gov/NHD_faq.html#q106)*

Route: In ArcGIS,refers to a linear feature, such as a street, highway, river, or pipe that has a unique identifier and a system of measurement. *(Adapted from ArcGIS 10.2 help reference)*

SDE Functions: Versioning, Reconcile, Post: *Versioning* allows multiple users to edit the same data in an ArcSDE geodatabase without applying locks or duplicating data. **Reconciling** and **posting** integrate your changes into any version that is an ancestor of the version you are working in, such as the parent or DEFAULT version. In the case of conflicting edits, users are able to review all proposed edits and choose which feature to retain. ArcGIS has special tools to manage and edit versioned SDE datasets. (*Adapted from ArcGIS 10.2 Help reference*)

Topological Editing: This refers to editing within an ArcGIS environment that has established **topopolgy rules** for how features within individual layers are spatially related. Specific tools are available to edit the shared boundaries of spatially-related features and to find and correct "errors" that violate pre-defined topology rules. *(Adapted from ArcGIS 10.2 Help reference*)

Topology: Topology is a collection of rules that, coupled with a set of editing tools and techniques, enables the (ArcGIS) geodatabase to more accurately model geometric relationships. Topology governs the geospatial relationships (such as adjacency and overlap) between different geographic features. These relationships are often governed by pre-defined **topological rules** such as "road lines of township type must be along the boundary of township polygons". *(Adapted from ArcGIS 10.2 Help reference*)

Topology Rules: ArcGIS implements **topology** through a set of rules that define how features may share a geographic space and a set of editing tools that work with features that share geometry in an integrated fashion. *(Adapted from ArcGIS 10.2 Help reference*)

United States Forest Service (USFS): A federal agency (part of the U.S. Department of Agriculture) that manages public lands in national forests and grasslands. They are also a forestry research organization that provides technical and financial assistance to state and private forestry agencies. *(Adapted from http://www.fs.fed.us/about-agency/newsroom/how-we-operate)*

United States Geological Survey (USGS): A science organization and federal agency that provides scientific information (including geospatial data) on environmental health, natural hazards, climate, land-use change and natural resources. *(Adapted fromhttp://www.usgs.gov/aboutusgs/)*

Water Resources Team (DNR): An interdisciplinary team of DNR staff responsible for maintenance of the enterprise **DNR Hydrography Dataset**.

Watershed: "It is common worldwide to use the terms *drainage area*, *catchment*, *watershed* and *basin* interchangeably in text and dialogue. The word watershed has become ambiguous representing many meanings across different disciplines. It is the opinion of the DNR Watershed Delineation Project staff that the use of "**Drainage Area**" is a better term for the general description of a watershed. However, it is often more practical, habitual, and widely accepted to use the word watershed in text and conversation." *(Vaughn, Sean. DNR Watershed Delineation Project: History, Methodology Terminology & Data Attribution.MNiT Services @ MN Dept. of Natural Resources, 2014, p.82)*

"A watershed or drainage basin is the area of land that drains water to a river, stream, orlake. Lake and stream watersheds are usually smaller components of river watersheds." *(http://files.dnr.state.mn.us/publications/waters/lakeshed_mapping.pdf)*

Watersheds can be classified as:

- **Classic Watershed:** A 'classic watershed'- (*or 'true watershed'-ed.)* - is a land and water area that has all the surface drainage within its boundary converging to a single point.
- **Remnant Watershed:** "Areas typically formed as residual areas after delineation of classic watersheds." When classic watersheds are defined of a given general size range, there will always be small areas left over that do not conform to the 'classic watershed' definition. These are 'remnant watershed areas' or 'remnant watersheds'. *(Federal Standards and Procedures for the Watershed Boundary Dataset (WBD) http://pubs.usgs.gov/tm/11/a3/)*

So the term watershed is used generically when describing drainage areas. For specifics of state DNR and federal WBD mapping this report uses the terms "DNR Catchments" , "DNR Hydrologic Units", "DNR Major Watersheds", "DNR Minor Watersheds", and WBD Hydrologic Units (HUCs), which are also defined in this glossary.

Watershed Boundary Dataset (WBD): A national geospatial dataset that contains the digitized boundaries of a 6-level (12-digit) hierarchy of watersheds created by the USGS. Each watershed defines the area-based extent of surface water drainage to a given point. *(Adapted from http://NHD.usgs.gov/wbd.html)*