AN INNOVATION IN WATERSHED STEWARDSHIP

Wetland Drain Restoration Project

“HOW TO GUIDE”

Enhancing Water Storage and Water Quality within a Watershed through Wetland Restoration

This guide was made possible by the Government of Ontario and the Norfolk Land Stewardship Council in partnership with the Norfolk County Public Works, Ducks Unlimited Canada, Eastern Habitat Joint Venture and the Ontario Wetland Habitat Fund.
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INTRODUCTION

The Wetland Drain Restoration Project has been an ongoing effort by the Ministry of Natural Resources, Norfolk County, and other significant partners since 1999. The project was developed in 1996 after the Norfolk Land Stewardship Council, former Township of Norfolk and partners successfully restored a wetland through a pilot project.

Since then, the Wetland Drain Restoration Project has allowed for the successful restoration of numerous wetlands in Norfolk County. Active wetland restoration is required to re-establish ecological functions, and the associated economic, social and cultural benefits (OMNR, Wetland Evaluation Technical Team, 2002). Targeted restoration sites have been within agro-ecosystems and provide measurable benefits to these communities and land-based operations.

Restored wetlands will function in a naturalized state and provide numerous benefits to the local community. Benefits include water purification, groundwater recharge and discharge, the maintenance of base flows in streams, sustained soil moisture for better crop production, improved ecosystem health and the provision of fish and wildlife habitat.

It is intended that this comprehensive "How to Guide" will help guide similar initiatives and facilitate successful wetland restoration efforts throughout Southern Ontario. The guide outlines strategic tactics and recommendations that have been developed and tested through the project's duration. The appendices of the guide provide specific wetland restoration methods and tools.

The goal is to realize the benefits of water quality improvement and water quantity regulation in association with restored wetlands. The project has received enthusiastic support with landowners, drainage superintendents, municipalities and resource management agencies throughout the agricultural belt of Southern Ontario. It is evident that there has been an increase in understanding of the social and community benefits provided by wetlands and their associated functions.
Much of the original wetlands in Southwestern Ontario have been converted to other uses through drainage. In today’s climate it has become apparent that wetlands have a natural capacity to store and transmit water in times of need as well as improve water quality and groundwater supplies. Consequently, wetlands act to improve the agroecosystem and human health (Spaling and Smit; 1995).

Significant water issues arose in agricultural areas across Southern Ontario in the summers of 1998, 1999, 2001 and 2002 due to lack of precipitation. These conditions negatively impacted crop yields and lowered the water table. These low water conditions were exasperated by the efficient removal of surface water by agricultural drains early in the growing season. The use of water for irrigation purposes and the lack of wetlands and their associated ability to store and release water later in the growing season are also contributing factors. Many streams and aquifers could not meet the water use demands and were depleted to critical levels.

It became obvious that innovative solutions were required to safeguard against future low water conditions and to improve the dependability of both clean and abundant water supplies. One of the most efficient and cost effective solutions was to promote the use of the Drainage Act as a tool to restore surrounding wetlands, without harming agricultural business objectives. Restoration involves extending the hydro-period within previously ditched and drained wetlands by increasing water storage in them, thus returning them to a more natural state. Water storage is achieved through methods such as drain naturalization, installation of water control structures, or bioengineering within those drains that remove water from wetlands.
A common method to restore wetlands is through the use of water control structures (low head structures). These structures allow water levels to increase in historical, natural wetlands, thereby contributing to the restoration of such habitats and water storage, without inhibiting the ability of farmers to drain portions of their land.

**PROJECT GOALS AND OBJECTIVES**

The Wetland Drain Restoration Project represents an ongoing effort by resource management agencies and landowners to balance the advantages provided by municipal drainage projects with the water purification, storage, recharge and discharge functions provided by wetlands. This will mutually benefit farming practices, local landowners, the environment and the local community. Restored wetlands can benefit landowners within the landscape without negatively affecting agriculture. Improved ecosystem health in the affected landscape will also benefit society as a whole.

The project also aims to create sustainable partnerships with community groups, landowners and natural resource agencies. This provides opportunities for education and advancement in natural resource, watershed and particularly wetland management.

**Audience**

Target audiences for implementing the Wetland Drain Restoration Project in the landscape include:

- Provincial and Federal government agencies
- Municipalities (i.e. Drainage Superintendents)
- Stewardship Ontario
- Conservation Ontario
- Special Interest Groups
- Private Landowners
Wetlands are a critical component of watersheds and landscapes in Ontario. Wetlands provide immeasurable benefits to society, within urban landscapes and rural agro-ecosystems. The following is a brief outline of wetland functions and wetland values:

**Water Quality Improvement**
Wetlands purify water through physical, biochemical and hydrogeological processes involving vegetation, microorganisms and percolation (Spaling and Smit; 1995). Suspended sediments, nutrients and other pollutants (including heavy metals) are assimilated or filtered by these wet areas. Furthermore, nutrients that are stored in wetlands in the spring will offset downstream eutrophication and reduce algal blooms in lakes. The availability of nutrients is then increased in the autumn, after the spring green-up by the release of stored water (A. Hill; 1976).

**Groundwater Recharge/Discharge**
Wetlands are often found in areas where the water table is close to the surface. In dry seasons water held within hydric soils is released as base flows within streams. It will also percolate into the underlying water table recharging groundwater supplies (Spaling and Smit; 1995).

**Flood Attenuation**
Wetlands form part of the catchment basin within a watershed. Their organic soils and generally flat topography can provide storage for large volumes of water. In addition, these spongy organic soils act to temporarily hold water that would otherwise breach stream banks and flood farm fields. Wetlands therefore reduce the incidence and intensity of flood peaks downstream (A. Hill; 1976).

**Fish and Wildlife Habitat**
Wetlands are essential habitat for many different species of plants, mammals, birds, reptiles, amphibians, fish, and invertebrates. Wetlands provide critical habitat for all or part of their life cycle. Wetlands provide habitat for game species such as ruffed grouse, wild turkey, white-tailed deer, and waterfowl. Fish such as trout, salmon, bass, northern pike, walleye and yellow perch utilize wetlands for forage, reproduction, nursery and rearing purposes.
Support of Cold Water Fisheries
Wetlands found in headwater areas provide the necessary aquatic environments and support for cold-water fisheries. Wetlands will regulate water levels and buffer against low water conditions, and will also regulate water temperatures and quality necessary for sustaining healthy downstream fisheries.

Social/Economical Benefit
The economical benefits of water quality, quantity, and retention are invaluable. Surface and ground water storage functions associated with wetlands improves agricultural crop production. Wetlands also provide recreation such as hunting, fishing, birding, and hiking. Marketable products produced by wetlands include trees, sport fish, furbearers, and food (Spaling and Smit; 1995). Swamps are especially noted for the production of large hardwood species.

Searching for a sustainable water supply to support agricultural business objectives during low water conditions.

Special Features
Provincially, regionally or locally significant plant and animal species are often found in wetland habitats. Rare species of flora and fauna as well as the rarity of the wetland itself may be valuable to society. It is unfortunate that wetlands remain undervalued in some sectors of society given their strong ecosystem functions and ecosystem services. Wetland losses in southern Ontario continue today and a key factor in the continuing losses of wetlands, and conversions to other uses, is the lack of awareness and understanding of how wetland functions benefit societal needs. The conservation of existing wetlands and restoration of wetland habitats provide a cost-effective and sustainable means of maintaining a healthy environment and thus an overall benefit to human health. The Wetland Drain Restoration Project focuses on identifying suitable sites for restoration to maximize wetland functions and benefits to the local communities. The step by step process of the Wetland Drain Restoration Project is illustrated in Figure 1.
Figure 1. Wetland Drain Restoration Project Flow Chart

1. Digital Maps of Wetlands (Appendix "A")
2. Digital Maps of Soil Drainage (Appendix "B")
3. Digital Maps of Drains (Appendix "A")

GIS

Wetland Drain Restoration Map (Appendix "C")

Site Selection/Ranking Criteria (Appendix "D")

List of Ranked Sites (Appendix "E")

Landowner & Municipality Contact (Appendix "F")

List of Accessible Sites

Landowner Questionnaire (Appendix "G")

List of Preferred Sites

Field Evaluation & Inventory (Appendix "H")

Feasibility Studies

Landowner & Municipal Approvals (Appendix "I")

Restoration Project Plans

Implement Restoration (Appendix "I")

Monitoring & Assessment

Restored Wetlands
To begin assessing landscapes and reveal potential restoration sites a desktop mapping method has been developed. The method also allows for efficient use of time and the reduction of project costs. The key is to identify potential wetland restoration sites that are presently being affected by municipal drains. A landscape map of these sites and a system to rank priority sites for further field investigation is the first critical step in a successful wetland drain restoration project.

Potential restoration sites and target areas are identified using digital mapping techniques. Basic mapping information that is compiled includes NRVIS (Natural Resource Values Inventory System) data. The NRVIS map data includes municipal drain locations, hydric soils, wetland locations, forest cover and streams. Additional information such as Permit to Take Water locations (MOE), potential wetland sites, and aquifer sites enhance the landscape map. Prioritizing sites will determine the order in which field investigations should be conducted.

The following Appendices provide a step by step process to create Wetland Drain Restoration Maps and prioritize sites on which to conduct feasibility studies:

**Appendix A: Digitizing Municipal Drains**, contains images from ArcView 3.2 software, showing View screens and attribute tables, to illustrate the digitization process of Municipal Drainage layers and the creation of associated attribute tables.

**Appendix B: Querying Poorly Drained Soils**, contains methods to sort hydric soils information.

**Appendix C: GIS Mapping Techniques**, contains methods for compiling data and revealing/displaying necessary landscape values.

**Appendix D: Desktop Methodology for Prioritizing Sites**, contains a list of materials needed to prioritize target sites for field investigations; and contains a step by step process list to follow, a procedure that helps to substantiate the legitimacy of targeted sites.
Appendix E: Ranking Spreadsheet, contains an example of prioritized sites, which also reveals the order in which field investigations will be conducted.

The desktop exercise has hopefully identified "best bet" sites for wetland restoration on the Wetland Drain Restoration Maps. Wetlands that show up on the map with extensive drainage should be considered as prime sites to implement Feasibility Studies. The next step is to determine if it is feasible to restore the wetlands identified in your desktop exercise. Feasibility field studies are one of the best tools to determine if wetland restoration is an option.

FIELD METHODOLOGY (Feasibility Studies)

Conducting in-field feasibility studies distinguishes sites that may be restored from otherwise unsuitable sites. Suitable sites are wetlands in which municipal drainage networks exist and where water may be stored, while maintaining and enhancing agriculturally based operations. Furthermore, candidate sites are those in which restoration will result in the re-establishment of wetland functions, specifically, water purification, storage, ground water recharge and discharge, as well as to provide for fish and wildlife habitat. In order for a site to be considered for restoration works, local landowner understanding, cooperation and consent is a must.

The following represents the base line data to be collected and addressed within feasibility studies:

- Landowner Support;
- Topography (Digital Elevation Models/Contours);
- Land Use (immediate and surrounding);
- Soil Types (looking for hydric soils from OMAF data);
- Hydrology (streams, aquifers, Permit to Take Water sites etc.);
- Municipal and Other Drainage Systems (closed & open);
➢ Drainage History (last clean out);
➢ Drainage Superintendent Support;
➢ Municipal Support;
➢ Fish Habitat (Species present, water temperature, migration);
➢ Landowner interests and perceptions (questionnaire, interviews, on site meetings);
➢ Wildlife and Vegetation Communities on and adjacent to the site;
➢ Degree of Effectiveness (Linkages to wildlife corridors, forest cover, headwater areas, think big picture within the landscape).

Be aware that Drainage Superintendent and landowner consent must be sought and provided prior to accessing any private lands.

The following Appendices provide a step by step process to conduct social and biological inventories at selected sites that have been chosen for feasibility studies:

**Appendix F: Landowner and Municipality Contact**, contains lists of necessary materials for contacting landowners and for pre-field study preparations.

**Appendix G: Landowner Questionnaire**, contains a sample of questions used to address social concerns and assess landowner views.

**Appendix H: Field Inventory Sheet**, contains a comprehensive spreadsheet outlining biological and ecological parameters, which must be inventoried and studied in the field and office.
Wetland Drain Restoration Project

DRAINAGE ACT OVERVIEW (APPLICABILITY AND PROCESS FOR WETLAND RESTORATION)

Applicability
The Ontario Ministry of Agriculture and Food manages several drainage-related statutes, one of which is the Drainage Act R.S.O. 1990, cD. 17. The Drainage Act involves democratic processes and therefore public and landowner involvement is the catalyst behind any changes to a drainage system. Responsibilities for implementing changes to a drainage system rest with the municipal council, usually through the advice of their appointed Drainage Superintendent(s), since the municipality remains liable for any changes imposed. Damming or diversion of surface water over 50 cubic metres a day requires a permit to take water issued by MOE office.

Subsection 78(1) of the Drainage Act is the main section that allows for the Wetland Drain Restoration Project to be implemented. Ss78(1) permits changes to be made to a drainage system to include such water management structures as dams, dykes and weirs etc. Furthermore, ss78(1) is activated by a Municipal Council decision to implement drain improvements that are usually based on recommendations from the local Drainage Superintendent(s) to the Council.

The Drainage Act legislation affords other advantages for the implementation and persistence of Wetland Drain Restoration Projects:

Project Permanency
Each restoration project is secured via by-law through Municipal Council's adoption of a Professional Engineer's report. The by-law gives each project legal status increasing the security of the restoration site since the project can only be abandoned through the repeal of the by-law following a defined process in the Drainage Act. The responsibility of maintenance and repair is assigned by the Act to the appointed Drainage Superintendent ensuring that the project will be properly managed.
The site restoration can only be altered through hiring an engineer under ss78(1) of the Drainage Act. Drainage Superintendent approval and recommendation is mandatory prior to a submittal to Municipal Council to hire an engineer to promote any change. Also, changes are only supported by virtue of the drainage system malfunctioning in the role or purpose developed.

Project Costs
When work is undertaken under a new engineer's report under the Drainage Act, the Ministry of Agriculture and Food (OMAF) may provide a one-third grant towards assessments imposed on agricultural land for this work. No grants are paid towards the assessments imposed on non-agricultural land.

The cost of the Professional Engineer's Report and physical alterations (Water control structure manufacturing and installation, maintenance etc.) to a drainage system are eligible for this grant. Once the project is completed, the grant can be claimed. The municipality must submit to OMAF a grant application form signed by the treasurer and the engineer along with all the necessary supporting documents.

Landowner assessments may be further subsidized through other funding sources.

Project Maintenance
After the project is constructed, Section 74 of the Drainage Act compels the local municipality to take responsibility and liability for maintaining the site and allows the municipality to assess the cost of the maintenance to the landowners in the watershed. Grants are available for maintenance work performed under the supervision of an approved drainage superintendent.
Wetland Drain Restoration Project

**DRAINAGE ACT PROCESS**

It is fundamental to remember that municipal drains are communal projects that are implemented by the local municipality, but paid for by the community of landowners. If the feasibility study identifies a candidate site for restoration, and all partners are in support of the recommendations, the following is a brief overview of the Drainage Act process that is to occur:

**Step One: Identify Need**
The municipal representative (usually the Drainage Superintendent) becomes aware of a need for improvement to the design of the drain, the result of either the landowner(s) request or the completion of a feasibility study.

**Step Two: Landowner Consent**
Landowner consent is received through signatures within a County/Township memorandum. Although this step is not required under the Drainage Act, it is important to gain the support of the landowners for this type of project as early as possible. Given that the wetland restoration has water quality and quantity benefits most landowners have proven to be very supportive.

**Appendix I: Municipality Memorandum**, contains a sample of a memorandum.

**Step Three: Municipal Council to Appoint Engineer**
The municipal representative (Drainage Superintendent), with the signed memorandum and feasibility study, prepares a report and recommendation to submit to Municipal Council. If the Council decides to accept the recommendations, the local Conservation Authority and Ministry of Natural Resources are notified and in accordance with ss78(1) of the Drainage Act, Council appoints a Professional Engineer to prepare a report outlining alterations to the drainage system.

**Step Four: On Site Meeting**
An on-site meeting is arranged by the Municipality to be held with the interested parties including the Professional Engineer, Drainage Superintendent(s), landowner(s), and project partner(s), to review alterations to the drainage system.

**Step Five: Preparation of the Engineer’s Report**
The Professional Engineer prepares a report outlining plans, profiles, and details for the recommended alterations. The report includes cost estimates and a schedule that shows how the cost of the project will be assessed to the individual landowners. The engineer is also responsible to ensure that all necessary approvals are obtained from the Federal Department of Fisheries and Oceans, the local Conservation Authority, and any other authorities that may have applicable legislation.

**Step Six: Engineer’s Report Submitted to Municipal Council**
The Engineer’s Report is presented at a Municipal Council meeting whereby all parties may voice concerns/support for the proposed alteration(s). The Municipal Council will either provisionally adopt the report by giving two readings to a by-law, or the report may be sent back for revision.
Step Seven: Appeals
If the report is provisionally adopted, the landowners involved in the drainage project have the right to appeal the report to the Court of Revision, The Drainage Tribunal or the Drainage Referee. It is anticipated that this situation should not occur since both the landowner and the Drainage Superintendent have indicated support for the project in the early stages of the process.

Step Eight: Construction/Implementation
After the appeal period, the municipal council may give third reading to the by-law, which then authorizes the construction of the project.

Detailed information on the drainage process can be obtained from your local Municipal Drainage Superintendent and are outlined in the Drainage Act.
PROJECT TACTICS/RECOMMENDATIONS

In-field feasibility studies will result in three basic recommendations:

1. No wetland restoration possible given that the municipal drain is functioning to provide agricultural benefits as per its original design or where landowner support cannot be obtained;
2. Some wetland restoration possible given that the municipal drain can act to store water without negatively impacting agricultural practices (through modification of the drain maintenance schedule);
3. Definite wetland restoration possible given that the municipal drain does not function to provide agricultural benefits in the given area (landowner and Drainage Superintendent input and approval required).

Should the second or third option be feasible, restoration may be achieved through various methods such as drain naturalization, installation of water control structures, and/or bioengineering methods. These tactics will extend the hydro-period within the affected wetland(s) and allow for the wetland(s) to be naturalized. Furthermore, installation of water control structures allows for flexibility and precision in restoration designs by allowing for the manipulation of water levels within the drain. Please note that maintaining a drainage outlet is necessary and legally binding to the municipality, unless the drain can be abandoned.

The design and placement of water control structures is dependant on the desired restoration outcomes which may include: hydration of wetland specific pockets, restoration of various wetland types, improved water recharge, discharge and improved water quality, modification or restoration of the drain hydro-period and/or regulation of the watershed hydrograph.

Appendix J: Restoration Design and Structures, samples of typical water control structure designs.

Detailed restoration designs and parameters are outlined in the Temperate Wetland Restoration Course Manual. The Temperate Wetland Restoration Training Course (TWRTC) is a six day course introducing resource professionals to basic principles, concepts and ideas on wetland restoration. Two days are spent in the classroom reviewing lessons learned from a synthesis of the science and practical experience from three decades of wetland restoration in North America. Four extensive field days are spent in the field looking at wetlands, wetland complexes, drained and degraded wetlands in the context of their watersheds. Focus is placed on important principles and concepts distilled from science synthesis and actual practice of doing wetland restoration projects.
LEGISLATION (APPROVALS FOR WORK ACTIVITIES)

Certain wetland restoration work activities (e.g., water control structure installation) will require the appropriate authorization under the acts listed below. Early communication and involvement of the appropriate agencies will ensure a timely review of proposed work activities.

Department of Fisheries and Oceans Canada
Fisheries Act (R.S. 1985, c. F-14)
Federal legislation containing habitat protection laws covering works which may result in harmful alteration or destruction of fisheries habitat.

Ontario Ministry of Natural Resources
Lakes and Rivers Improvement Act (R.S.O. 1990, cL. 3)
Provincial legislation requiring the approval of works on rivers or streams, including the construction and alterations to dams or other works.

Ontario Ministry of the Environment
Ontario Water Resources Act (R.S.O. 1990, cO. 40)
Provincial legislation covering the taking of water and the protection of water quality.

Conservation Ontario
Conservation Authorities Act (R.S.O. 1990, cC. 27)
Provincial legislation administered by Conservation Authorities requires a permit prior to alteration or construction within waterways.

PROJECT OUTCOMES AND DELIVERABLES

Restoring wetlands by extending the hydro-period in target sites will result in restoration of some wetland functions. Therefore, associated outcomes from the Wetland Drain Restoration Project include:

Impaired fen due to drainage, now under successful restoration.
Outcomes
➢ Increased wetland habitat within Southern Ontario ecosystems;
➢ Slowing the rate of loss of the past trend of continuing wetland loss in Ontario;
➢ Improved water quality within affected landscapes;
➢ Enhanced carbon sequestration in wetlands;
➢ Improved surface and ground water storage, discharge and recharge functions during dry periods;
➢ Enhanced ability of the landscape to buffer against drought conditions;
➢ Improved stream base flows (and stream temperature regulation);
➢ Soil conservation;
➢ The provision and support of fish and wildlife habitats (and associated recreational opportunities);
➢ Improved agro-ecosystem health with the coexistence of wetlands and municipal drains and established buffer zones between natural areas and agriculture;
➢ A unique way to utilize the Drainage Act for the betterment of the environment, while co-existing with sustainable agriculture:
  ● Up to 1/3 grant from OMAF after project completion;
  ● Democratic process that involves landowners and increases their awareness of municipal drainage capabilities;
  ● Increased landowner awareness of wetlands for their water supply benefits and associated functions;
  ● Incorporation of Wetland Drain Restoration Projects within Professional Engineers report adopted by municipal by-law assures longevity of the project despite future landowner changes;
➢ Municipal responsibilities for the repair and maintenance of all drainage projects including any wetland restoration projects undertaken under the Drainage Act;
➢ Potential reduction of drain maintenance costs through modification of drain management schedule and use of environmentally friendly management techniques;
➢ Increased public awareness of the importance of wetlands;

Excellent riparian buffer potential downstream from wetland restoration site.
Improved landowner awareness of land stewardship and improved understanding of the influence that their land practices have on surrounding areas and water supplies (quality & quantity);

The fostering of a spirit of cooperation between farmers and other community groups;

Improved understanding among project partners will lead to other joint projects benefiting the environment;

Overall economic benefits for society as a whole.

Deliverables

- The completion of Landscape Feature mapping and choosing “Best Bets” for new restoration work;
- Development of educational materials to maintain project momentum and communicate results to other interested agencies, landowners, municipalities and Drainage Superintendents;
- Pre- and post-construction monitoring to demonstrate wetland restoration benefits;
- Increase information base on wetlands, streams, aquifers, municipal drains, permit to take water locations and low water data to be shared between resource management agencies and community groups.

PARTNERSHIPS AND SOCIAL ASPECTS

The Wetland Drain Restoration Project involves a wide diversity of partners, increasing the understanding of wetlands and their benefits to communities, as well as, improved understanding of each other.

Partnerships both strengthen and enhance the transferability of a project, as they allow for shared expertise, respect, communication, flexibility, education, monitoring, and in-kind and financial support. Successful partnerships minimize conflicts among resource uses and users. Also, there is an immeasurable synergistic value of partners working together to achieve more benefits than individual parties working alone.
All partners must be committed to open communications, fairness, and transparency. The benefits to each partner, roles and responsibilities and jurisdictions must be clearly outlined and understood.

Furthermore, establishing partnerships with landowners requires ongoing and long-term dedication. Partnerships should be nurtured and continue throughout the project implementation and into the future, alongside monitoring tactics.

Partnership models and ideals are described within the Ontario Ministry of Natural Resources, Beyond 2000 document and the Ontario Stewardship Model. Both exemplify integrated resource management objectives, which address the full range of environmental, social and economical factors in any endeavor.

PUBLIC EDUCATION AND AWARENESS

The Wetland Drain Restoration Project uses the Principles of Ontario Stewardship, which include respect for private land ownership, working together in the community to pool available resources and helping people to help themselves. Therefore, the Wetland Drain Restoration Project encompasses a broad strategic approach to managing the environment where implementation is shared across jurisdictions and agencies.

A diverse partnership of agencies, landowners, farm organizations and municipalities is created that works together towards a common cause, ensuring a sustainable environment through wetland restoration. Furthermore, the project’s approach is based on shared responsibility with the government and non-government organizations, local municipalities, local landowners, the public and the scientific/technical community, and relies on transparent sharing of information. A Wetland Drain Restoration Project Advisory Committee has been established to guide the project as it expands in the Southern Ontario landscape.
The Wetland Drain Restoration Project involves a place-based approach with environmentally derived boundaries such as watersheds. Municipal drains are organized on a sub-watershed basis and thus lend themselves to a watershed management approach. This project marries organizations and individuals that work in terms of municipal boundaries with organizations that work on a watershed basis and who both wish to influence management of private lands at a landscape or ecosystem scale.

Use of digitized mapping products including streams, municipal drains, wetlands, water taking permit locations, hydric soils, forest cover and aquifers will facilitate improved understanding of watersheds and improved communication between agencies with different interests but affecting the same water supplies. Furthermore, the sharing of project data among resources agencies and community groups will increase the ability of all parties to better manage water quality and quantity issues within the watershed.

Linkages to existing related initiatives will ensure sharing of information between respective communities. Additionally, products from the project will assist organizations and landowners with similar concerns and interests in neighbouring watersheds or municipalities, to implement similar projects.

Finally, the diversity of partners involved in the Wetland Drain Restoration Project and the democratic process required under the Drainage Act assures that a strategic shift towards shared responsibility and awareness and the need for sustainable agricultural and natural environments, amongst all stakeholders, will be accomplished. Each restored site should necessitate a monitoring and evaluation plan. Monitoring may also extend throughout or encompass the watersheds in which the restored wetlands are situated.

**PROJECT MONITORING**

Each restored site should necessitate a monitoring and evaluation plan. Monitoring may also extend throughout or encompass the watersheds in which the restored wetlands are situated.

Monitoring techniques may vary depending on project objectives. Since the knowledge of a site's hydrology is known to be fundamental to the structure and functioning of wetland systems, either direct or indirect hydrologic monitoring should be included in all plans. Some examples of useful and comprehensive studies involve vegetation plots and/or transects to monitor habitat changes, which can demonstrate the changing hydrology indirectly. Photo stations are a tool to monitor changes in vegetative communities due to wetland restoration actions. It is the assumption that wetland dependant species will succeed back into the site, as the site is restored toward a natural functioning wetland. Surface water levels, soil moisture, local and regional groundwater levels and climatic influences are direct measures of hydrology and are important in monitoring programs.
Basic water quality data may also be collected and assimilated, if improvement of water quality is one of the project objectives. Direct measurements of water chemistry or quality (e.g.: denitrification is likely and should be assessed), or indicator organisms such as benthic invertebrates can be used to evaluate water quality.

Lastly, habitat monitoring for the presence of bio-indicator species will reveal certain aspects of ecosystem health. Local field naturalists can be involved in monitoring wildlife populations, particularly amphibians or birds.

Monitoring must take place across space and time in a comprehensive manner so that it may reveal:

➢ The results of each restoration program objective;
➢ The effectiveness of the restoration design and implementation;
➢ Annual and long term success of the project;
➢ The short and long term impacts on:
  ● benefits to the environment;
  ● benefits to wildlife (habitat);
  ● benefits to the local community;
  ● benefits to landowners;
➢ The necessity for alterations to the restoration plans;
➢ Assessment of future needs.

Pre-restoration information (baseline data) should be gathered for each monitoring project. Even basic hydrologic data is useful in planning a more successful restoration. Furthermore, attempts to collect historical data should be undertaken where possible. Lastly, monitoring should continue during and after the restoration, and should be conducted over a minimum of a 2-year (8 season) period, although years of monitoring are needed to fully evaluate a restoration, due to the slow development of ecosystems and chance hydrologic events.
CONCLUSION

There is now a strong movement to protect and restore wetlands after decades of thinking of wetlands as a wasteland or impediments to agricultural business objectives. This change in attitude is due to societies new found understanding of the enormous ecological and societal value wetlands provide. A wetland's ability to improve water quality and quantity in the landscape is, and will continue to be, extremely important to addressing human health issues.

It is intended that this comprehensive Wetland Drain Restoration "How to Guide" will help guide similar initiatives and facilitate successful wetland conservation and restoration efforts throughout Southern Ontario. The Wetland Drain Restoration process requires that you do your homework through the Feasibility Studies, take action on the recommendations in the Feasibility Studies, monitor the results of the restoration actions implemented and adjust the restoration activity as necessary.

It is strongly suggested that Wetland Drain Restoration project members be contacted to assist with the initiation of wetland restoration efforts associated with municipal drain water regime manipulation given their strong skills developed from "learning from doing". Each restoration project is an experiment and the sum of the results provides a context for future restoration actions.

Water quality, quantity and wetland function restored; a successful outcome to a Wetland Drain Restoration Project.
Key Contacts:
Dave Richards, Management Biologist, Long Point Area, Ontario Ministry of Natural Resources, Aylmer District.
Phone # (519) 773-4731.
Email: dave.richards@mnr.gov.on.ca

Peter Bryan-Pulham, Senior Drainage Superintendent, Norfolk County.
Phone # (519) 582-2100 Ext. 601. Email: peter.bryan-pulham@norfolkcounty.on.ca

Dave Reid, Stewardship Coordinator, Norfolk Land Stewardship Council.
Phone # (519) 426-4259.
Email: dave.reid@mnr.gov.on.ca

Demonstration Sites:
Garnham Drain Wetland Restoration
Big Marsh Drain Wetland Restoration
Walther’s Overflow Wetland Restoration
Fick Drain Wetland Restoration
Dry Creek Drain Wetland Restoration
Acorus Wetland Restoration
VanSeveren Wetland Restoration
GLOSSARY OF TERMS

Agro-ecosystem: Any agricultural system, which incorporates a natural community of plants and animals within a particular physical environment, on land where domestic animals are raised or crops grown.

Aquatic: Growing or living in water.

Benthic: Occurring at the base of bodies of water: lakes, oceans, and seas.

Bioengineering: The application of biological science to engineering principles. The use of living or organic plant material to achieve engineering solutions.

Carbon Sequestration: Process by which Carbon is removed from the environment and held within, for example, a wetland.

Conservation: The protection of natural or man-made resources and landscapes for later use.

Drainage System (Under the Drainage Act): A drain constructed by any means, including works necessary to regulate the water table or water level. This broad definition allows for features to be included in drainage systems to restore wetlands while still protecting the agricultural interests of the private landowners.

Drained: A condition in which the level or volume of ground water or surface water has been reduced or eliminated from an area by artificial means.

Ecosystem: A natural community of plants and animals within a particular physical environment, which is linked by a flow of materials throughout the non-living (abiotic) as well as the living (biotic) section of the system.

Enhancement: To add to, or to make greater; for example, to add additional water to a wetland, in order to make greater its' environmental functionality.

Function: An ecological role for human benefit.

Groundwater: All water found under the surface of the ground that is not chemically combined with any minerals present, but does not include underground streams.

Groundwater Discharge: The function of a wetland to accept subsurface water and hold it for release over long periods of time.

Groundwater Recharge: The function of a wetland to retain large quantities of water for slow percolation to replenish groundwater supplies.

Hydric Soil: Soil characterized by an abundance of moisture and much reduced oxygen levels, to the extent that the soil supports water-tolerant vegetation.
**Hydrology:** The study of the earth's water, particularly of water on and under the ground before it reaches the ocean or before it evaporates into the air.

**Hydro-period:** The seasonal pattern of the water level of a wetland that is a hydrologic signature of each wetland type. It defines the rise and fall of a wetland's surface and subsurface water.

**Hydrophytic Plants:** Vegetation adapted to growing in water or in hydric soils.

**Intermittent:** Stopping and beginning again, pausing at intervals, for example, water flow.

**Monitoring:** Periodic evaluation of a site to determine success in achieving goals.

**Naturalize:** To make a part of the physical environment natural, free from conventional characteristics.

**Poorly Drained:** Soils that are saturated at or near the surface during a sufficient part of the year such that field crops cannot be grown without drainage.

**Restoration:** Changing existing function and structure of wetland habitat so that it is similar to historical conditions.

**Values:** Wetland processes or attributes which are beneficial to society.

**Water Control Structure:** An engineered structure designed to hold back water and mimic a natural water regime that promotes wetland restoration, without affecting adjacent agricultural practices.

**Watershed:** The boundary between two river systems. The watershed marks the divide between drainage basins, and usually runs along the highest points of elevation.

**Water Table:** The surface below which the soil is saturated with water.

**Wetland:** Lands that are seasonally or permanently covered by shallow water, including lands where the water table is at or very close to the surface. In either case, the presence of abundant water has caused the formation of hydric soils and has favoured the dominance of either hydrophytic or water-tolerant plants.

**Wetland Values:** Wetland processes or attributes which are beneficial to society.
ACKNOWLEDGMENTS

The Wetland Drain Restoration Project would like to thank the Advisory Committee for their expertise, commitment and interest:

➢ Dave Richards, Project Lead and Management Biologist, Long Point Area, Ontario Ministry of Natural Resources, (519) 773-4731;
➢ Peter Bryan-Pulham, Senior Drainage Superintendent, Norfolk County, (519) 582-2100 Ext. #601;
➢ Shawn Vanacker, Drainage Superintendent, Norfolk County, (519) 582-2100 Ext. #602;
➢ Leora Berman, Wetland Drain Restoration Project Coordinator, Ontario Ministry of Natural Resources, 2001-2002;
➢ Kate MacIntyre, Wetland Technician, Ontario Ministry of Natural Resources, 2003;
➢ Dave Reid, Coordinator, Norfolk Land Stewardship Council;
➢ Robert Messier, Ontario Wetland Habitat Fund Advisor;
➢ Sid VanderVeen, Drainage Coordinator, Ontario Ministry of Agriculture and Food;
➢ Russ Piper, Past President, Ontario Federation of Anglers and Hunters and member of the Ontario Drainage Tribunal;
➢ Larry VanSeveren, Landowner/Realtor and member of Norfolk Land Stewardship Council;
➢ Paul Gagnon, Lands and Waters Supervisor, Long Point Region Conservation Authority;
➢ John Warbick, Hydrogeologist, Ontario Ministry of the Environment;
➢ Sarah Bod, Monitoring Technician and Masters Student, University of Western Ontario;
➢ Dave McLachlin, Biologist, Ducks Unlimited Canada;
➢ Dana Boyter and Joe DeLaronde, Biologists, Department of Fisheries and Oceans Canada.

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➢ Nancy Wolfe, GIS Data Clerk, Ontario Ministry of Natural Resources;
➢ Dean Kebbel, GIS Officer, Ontario Ministry of Natural Resources;
➢ Brad Graham, Information Management Supervisor, Ontario Ministry of Natural Resources;
➢ Jill Ostrowercha, Norfolk County Drainage Clerk;
➢ Richard Drouin and Tim Marchand, GIS Technicians, Ontario Ministry of Natural Resources;
➢ Brian Potter, Wetland Evaluation Technical Team lead, Ontario Ministry of Natural Resources;
➢ Angus Norman, Wetlands/Wildlife Specialist, Ontario Ministry of Natural Resources;
➢ Kevin Loftus, Wildlife Program and Eastern Habitat Joint Venture Coordinator, Ontario Ministry of Natural Resources;
➢ Mark Stabb, Program Manager, Ontario Wetland Habitat Fund.
➢ Dave Dixon & Amber Spicer, Summer Experience Program, Ontario Ministry of Natural Resources.
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Norfolk County;
Norfolk Land Stewardship Council;
Norfolk Water Supply Enhancement Project;
Ontario Federation of Anglers and Hunters;
Ontario Ministry of Agriculture and Food;
Ontario Ministry of Environment (Watershed Management Pilot Project);
Ontario Ministry of Natural Resources -
    (Eastern Habitat Joint Venture Program; Fish and Wildlife Capital Program;
     Community Fish and Wildlife Involvement Program and Ontario Living Legacy
     Protection and Enhancement Program);
Ontario Stewardship Opportunity Fund;
Ontario Wetland Habitat Fund/Wildlife Habitat Canada;
The Ontario Trillium Foundation;
The University of Western Ontario.

The Wetland Drain Restoration Project would like to thank all landowners for participating in wetland restoration in Southern Ontario. Without you there would be no project. Thank You!
REFERENCES


SUGGESTED READINGS

A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern. Environment Canada, MNR, MOE.


Buffer Action, Improving Water Quality. Produced by the Livestock Manure Pollution Prevention Project, a sub-committee of Ontario Farm Environmental Coalition.


The Drain Primer. A Guide to Maintaining and Conserving Agricultural Drains and Fish Habitat. Produced by the Drainage Superintendents Association of Ontario and Ontario Federation of Agriculture in association with Fisheries and Oceans Canada.

So What is a Municipal Drain? Norfolk County Public Works and Environmental Services Department.


Wildlife Wise. A collection of articles originally prepared for the farm media under the direction of Ontario Soil and Crop Improvement Association as part of a communication initiative funded by the Ontario Ministry of Natural Resources.
Digitizing Municipal Drains
In ArcMap, Municipal Drain Maps may be georeferenced to a GIS Layer. Here the road layer (shapefile) is used.
Figure 2: Imported Municipal Drain Map

The Municipal Drain map is imported into ArcMap as a TIFF file at a high resolution. Control Points are used to georeference the TIFF features against the Roads within the GIS layer.
Control Points are matched against the chosen/appropriate GIS layer until the two maps are overlain.
Use of control points will maneuver the Municipal Drain TIFF map within the GIS layer view. Once the Municipal Drain Map Features match the scale, orientation, proportions and location of the features within the GIS layer, the Municipal Drain Map must be rectified.
Figure 5: Creation of Municipal Drain GIS Layer

A Shapefile and Attribute table (to display Municipal Drain information) is created. The Shapefile consists of individual polylines which are traced from the rectified Municipal Drain TIFF map.
Figure 6: Attributes of the Municipal Drain GIS Layer

Each Municipal Drain that is traced is named within the associated Attribute Table.
Querying Poorly Drained Soils
OMAF GIS Data is brought into the ArcView View Screen.
Figure 2: OMAF Soils Attribute Table

OMAF GIS Soils Attribute Table is opened and reveals associated fields, including soil descriptions or codes.
A soils table is created. The file uses field descriptions from the OMAF Soils Attribute Table and includes an additional field to describe drainage associated with each type of soil.
Figure 4: Joining Attribute Tables

The table is saved as a text file and is added to the ArcView Project. The two tables are joined to create an OMAF Attribute Table complete with soil drainage descriptions for each soil type/code.
Figure 5: Improved Attribute Table to be Queried

The extended OMAF Attribute Table can now be queried to reveal all poorly drained and hydric soils.
Figure 6: Poorly Drained Soils Within Attribute Table

Once queried, the selected features may be converted to a shapefile to display polygons of these wetland soils.
GIS Mapping Techniques
Figure 1: Poorly Drained Soils

In ArcView, the newly created Shapefile containing polygons that outline poorly drained or hydric soils is placed in the View.
Figure 2: Finding Treed Swamp Wetlands

A Forest Cover Layer overlays the Poorly Drained Soils layer to reveal treed swamplands where the two polygons overlap.
The Municipal Drain Layer/Shapefile is brought into the View. Potential restoration sites are areas where treed swamps (poorly drained soils overlain by tree cover) are intercepted by Municipal Drains.
Other landscape features may be placed within the View to reveal advantages and obstructions to restoration works.
Spring Infrared Aerial Photography is used to back up inferences made through the mapping process. Notice the wet pockets (pink outline) within the treed swamp and the drainage patterns (yellow lines) in the landscape.
Methodology for Prioritizing Sites
Methodology for Prioritizing Feasibility Studies
Wetland Drain Restoration Project

Materials
✓ ArcInfo
✓ Arcview 3.1
✓ Municipal Drainage Maps
✓ Aerial photography
  • 1978 black and white
  • 1998 Infra-red aerial photography
✓ 1996 Provincial Land Coverage
✓ OMAFRA Soils data (includes land use coverage and soil information)
✓ 1972-1978 Forest Resource Inventory Maps
✓ area upland/lowland forest mapping
✓ area unidentified wetland mapping
✓ Evaluated wetlands (PSW, NPSW)
✓ NRVIS layers (roads, vegetation, wetlands, wooded areas, waterlines, water polygons, and lots and concessions

Methods
The following procedure has been incorporated from the Temperate Wetland Restoration Course, “Section 3, The Planning Process.” Each site was evaluated according to the process outlined below:

A. Goals and Objectives
Goals: Identify which wetlands including potential wetlands, are being impacted by municipal drains
Objectives: To restore the wetlands natural ability to retain water
          To restore the wetlands ability to maintain baseflow through the discharge of water over time
          To create a partnership with local stakeholder groups
          To educate the local community and make them aware of water related issues
          To conserve and enhance fish and wildlife habitat

B. Is the Site a Wetland?
✓ Yes the site is a known wetland  See Criteria D
✓ Unknown  See Criteria C

C. If the site is unknown then:
A number of resources were used to do an in house assessment of the woodlot in question. The following procedure was used to discriminate between potential treed swamps and non-treed swamps. The assumption made was that if the following criteria were met, then there was a high probability that somewhere in the wooded area there is situated a wetland:
Unevaluated wetlands were previously identified in an early project. The unevaluated boundary lines were converted from 1978 black and white photography to a digitized form via on screen digitizing. Soil drainage type is described as poorly drained.

- Data provided by OMAFRA Soils data set
- Soils data was converted from coverage to shape file in ArcView 3.1
- The shape files were merged together to get complete coverage of the study area
- The soil layers were then clipped to their respective township maps
- OMAFRA data tables were edited to create standard set tables
- Soil description table created by Brad Graham (MNR, Aylmer) were joined to the OMAFRA data set
- This process allowed for Querying out “Poorly Drained Soils”
- Assumption is that there is a good probability that, by overlaying the Wooded Area on top of Poorly Drained Soils that this would be a good indication of wetland

Dominant Vegetation Type

- Review of the Forest Resource Inventory maps were used to strengthen support for the idea that, “Wooded areas growing on Poorly Drained Soils should be dominated by hydrophilic plants or water tolerant vegetation”
- Those woodlots with the greatest percentage of wetland indicator trees were favoured over areas with little or no wetland indicator species

Upland/Lowland Forest

- For increased confidence, woodlots were then compared to an Upland/Lowland Forest map

D. Does a municipal drain directly impact the wetland?

- Municipal drain maps were provided by the Municipal Drainage Engineer
- Drains were on screen digitized
- Direct impacts were verified by overlying, evaluated and unevaluated wetlands, poorly drained soils and wooded area with the municipal drain layer.

E. Size of Wetland

- Using the concept “Bigger is Better”, the study areas were assessed based on their size. The assumption is that larger areas are able to provide more habitat layers; therefore, supporting greater species diversity and richness. This also is a reflection of the study area’s health and it’s ability to recover from extreme events.
F. PSW/NPSW (Unevaluated)

- Provincially Significant Wetlands were ranked at a higher level than those that were not provincially significant. Non-Provincially Significant wetlands may have lower Evaluation scores, however they may be locally significant and valuable in terms of species richness, diversity and hydrological impact. Furthermore, NPSWs were known wetlands with historical data already recorded and compiled, therefore NPSWs were ranked higher than unevaluated / “unknown” wetlands.

G. Distance to other Natural Areas

- Location, location, location. Areas were assessed based on their proximity to other natural areas. Mitigating the impacts of drainage will not only restore the wetlands’ natural ability to function, but also enhance the surrounding fish and wildlife habitat.

H. Position in Watershed

- Headwater areas were ranked highly for their ability to support downstream hydrology, and therefore aquatic habitats. Furthermore, headwater areas that were at the greatest topographical relief were valued for their ability to recharge groundwater (recharge zones). Areas at a lower relief and in the middle of a watershed were ranked beneath top headwater areas: these areas may be recharge and discharge zones. Areas situated close to the watershed outlet, as well as at a lower elevation were likely groundwater discharge zones which may be suited for water purification, however would not support surrounding hydrology and aquifers to the same extent as those wetlands at higher elevations and in headwater areas.

I. Adjacent Lands/Size of Buffer Area

- What are the direct impacts? Potential flooding of adjacent lands, residence etc.

Each of the evaluated and unevaluated wetlands were subjected to the above criteria and ranked accordingly. Ranking system could and may change depending on two critical details:

1. Municipal Drainage Engineer acceptance to complete the work
2. Most important: LANDOWNERS WILLINGNESS TO PARTICIPATE
Sample Ranking Spreadsheet
## Ranking Spreadsheet for the Wetland Drain Restoration Project

<table>
<thead>
<tr>
<th>Wetland ID</th>
<th>Location</th>
<th>Concession</th>
<th>Watershed</th>
<th>Rank</th>
<th>Status</th>
<th>Recommendation/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>MI-13</td>
<td>Middleton</td>
<td>142-147</td>
<td>Talbot Road East South</td>
<td>A1</td>
<td>Study Conducted 2000</td>
<td>Scores extremely high for soils and dominant vegetation type. Forest Management identifies east half as lowland forest. Extremely large site with many habitat benefits.</td>
</tr>
<tr>
<td>WI-15</td>
<td>Windham</td>
<td>12, 13</td>
<td>Big Creek</td>
<td>A2</td>
<td>Study Conducted 2000</td>
<td>Headswaters to Windham Creek. Verify if evaluated (WI-15) and data not captured by NRVIS. Idle land in the area - Stewardship Restoration Project. Good site because Drain impacts on WI-15.</td>
</tr>
<tr>
<td>NW-20</td>
<td>North Walsingham</td>
<td>7, 8</td>
<td>Venison Creek</td>
<td>A3</td>
<td>Study Conducted 2000</td>
<td>Potential, but area directly impacted by drain is relatively small compared to the entire woodlot. Consider north woodlot, soils and vegetation strongly suggest wetland. Should be evaluated.</td>
</tr>
<tr>
<td>WI-55</td>
<td>Windham</td>
<td>13/14</td>
<td>Big Creek</td>
<td>A4</td>
<td>Study Conducted 2000</td>
<td>Good area - high density of drains and wetlands. Should be evaluated and complexed with WIND1 (PSW).</td>
</tr>
<tr>
<td>MI-7</td>
<td>Middleton</td>
<td>156</td>
<td>Talbot Road East South</td>
<td>A5</td>
<td>Study Conducted 2000</td>
<td>Good site - Size may be limiting. Drain splits into four - three impacting wet area (headswater to trib. Of Little Otter). May be as simple as backfilling in the drain.</td>
</tr>
<tr>
<td>CH-28</td>
<td>Charlotteville</td>
<td>6</td>
<td>Headwaters to Dedrich</td>
<td>A6</td>
<td>Study Conducted 2001</td>
<td>This is a good site to consider. Notes: woodlot to the north, where drain originates, strongly suggest wet area. Consider both sites when evaluating.</td>
</tr>
<tr>
<td>MI-19</td>
<td>Middleton</td>
<td>26-29 167-170</td>
<td>Con.2 North Talbot Road Talbot Road East North Little Otter Big Creek (South Creek Headwaters)</td>
<td>A7</td>
<td>Study Conducted 2000</td>
<td>Large area with lots of potential. Highly impacted by several drains plus private drains. 1982 OMAFRA data identifies some idle land which can be included in the restoration project. Consider both sites when evaluating.</td>
</tr>
<tr>
<td>WI-10</td>
<td>Windham</td>
<td>1,2,3</td>
<td>Nanticoke</td>
<td>A8</td>
<td>Study Conducted 2001</td>
<td>Good area with two extensions of the Prescott Drain originating from this area. Should be evaluated and complexed with NC-1 (PSW).</td>
</tr>
<tr>
<td>NW-9</td>
<td>North Walsingham</td>
<td>1, 2</td>
<td>Headwater to trib. Of Venison</td>
<td>A9</td>
<td>Study Conducted 2001</td>
<td>Good area with moist soils.</td>
</tr>
<tr>
<td>CH-36</td>
<td>Charlotteville</td>
<td>7, 8</td>
<td>Con. 4</td>
<td>B10</td>
<td>Study Conducted 2000</td>
<td>Area is good because of size and location. Woodlot definitely has wet areas and should be evaluated. However area impacted by drainage appears to be least wet. Significant habitat - interior forest habitat.</td>
</tr>
<tr>
<td>CH-32</td>
<td>Charlotteville</td>
<td>4, 5</td>
<td>Conc. 4</td>
<td>B11</td>
<td>Study Conducted 2000</td>
<td>Area is wet, with large pools of water within the woodlot. However area impacted by drainage occurs along the north east corner among soft maple barren.</td>
</tr>
<tr>
<td>HO-19</td>
<td>Houghton</td>
<td>1,2</td>
<td>2</td>
<td>B12</td>
<td>Study Conducted 2001</td>
<td>High concentration of drains in the area. Plus a high concentration of wetlands - SOC-4 to the west, SOC-3 to the east. Need to focus on headwater area.</td>
</tr>
<tr>
<td>HO-32</td>
<td>Houghton</td>
<td>11, 12</td>
<td>5</td>
<td>B13</td>
<td>Study Conducted 2001</td>
<td>Depending on Hydroperiod water control structure may not be feasible due to road upstream. May be restricted to smaller area east of road. Note: upstream Shia woodlot, where drain originates, soils and vegetation indicate wetland area.</td>
</tr>
<tr>
<td>Wetland ID</td>
<td>Location</td>
<td>Township</td>
<td>Lot</td>
<td>Concession</td>
<td>Watershed</td>
<td>Rank</td>
</tr>
<tr>
<td>-----------</td>
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<td>----------</td>
<td>-----</td>
<td>------------</td>
<td>-----------------</td>
<td>------</td>
</tr>
</tbody>
</table>
| WI-44     | Windham        | 9        | 12  |            | Lynn River      | C    |                 | Need to investigate further  
50% swamp like species, but may only be small pockets of wet area  
Located in a high drainage density area                                                                                                                                                                                                                                                                                                                                 |
| HO-7      | Houghton       | 1        | 16  |            | South Otter     | C    | Study Conducted | 2001 Area of interest is upstream of where 1999 filed survey was conducted  
Area of interest is a mixed forest with Pine plantation to deciduous forest  
Poor vegetation community with only 40% soft maple                                                                                                                                                                                                                                                                                                                                 |
| HO-12     | Houghton       | 2        | 13  |            | South Otter     | C    |                 | Lots of water flowing  
Soils and vegetation appear good but site is limited by size (2ha)  
May be supported by wetland SOC-2 (PSW)  
Area downstream already dammed for irrigation of tobacco                                                                                                                                                                                                                                                                                                                                 |
| NW-29     | N.Walsingham   | 9        | 7   |            | Big Creek       | C    |                 | Site visit suggest upland: Forest Management identifies it as upland forest: Forest Inventory and Soils suggest wet  
Not a direct impact of drain on wetland  
Needs a closer investigation to verify location of wetland in relation to drain  
Plus size of wetland, which is limiting (1.5 ha)  
Area downstream already dammed for irrigation of tobacco                                                                                                                                                                                                                                                                                                                                 |
| NW-5      | N.Walsingham   | 14 - 15  | 13  |            | Big Creek       | C    |                 | Poorer soils and low wetland dominant species  
Wet areas may be restricted to small wet pockets  
May be beneficial to pursue later on due to its relation to 132 ha hardwood forest and coniferous plantation                                                                                                                                                                                                                                                                                                                                 |
| SW-22     | S.Walsingham   | 1        | 2   |            | Tributary to Lake Erie | C    | Limited by size (4ha) | Can be supported by PSW BC 29  
Contour line suggest that drain is a continuation and channelization of the natural drainage system  
May be CFIP project / Stewardship                                                                                                                                                                                                                                                                                                                                 |
| CH-36     | Charlottesville| 8        | 3   |            | Forestville     | C    |                 | Forest Inventory suggest upland forest  
Infra-red aerial photograph suggest pockets of very wet soils  
Location of drain to soils indicates a good potential for wetland restoration  
Size and location of wetlands limiting  
Contourline shows a transition from higher land to lower land  
Need to investigate further                                                                                                                                                                                                                                                                                                                                 |
| CH-43     | Charlottesville| 2 & 3    | A - B|            |                 | C    |                 | Area has been identified has having wet soils; but Forest Inventory shows a Mix Deciduous  
Forest typical of upland forest  
Possibly small pockets of wetland within large forested area  
Encroachment is occurring  
Areas which may be in succession; marginal land with mix wetland, deciduous forest, coniferous stands and possible low shrub grasslands  
Stewardship Program to manage significant habitat                                                                                                                                                                                                                                                                                                                                 |
<table>
<thead>
<tr>
<th>Location</th>
<th>Township</th>
<th>Wetland ID</th>
<th>Lot</th>
<th>Concession</th>
<th>Watershed</th>
<th>Rank</th>
<th>Status</th>
<th>Recommendation/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH-35</td>
<td>Charlotteville</td>
<td>CH-35</td>
<td>8</td>
<td>2</td>
<td>Forestville</td>
<td>C</td>
<td>Study Conducted 2000</td>
<td>Wet areas appear to be weakly affected by drain Dam already located in immediate vicinity Municipal drain appears to be a modification (channelized/dredged) of the natural system</td>
</tr>
<tr>
<td>MI-16</td>
<td>Middleton</td>
<td>MI-16</td>
<td>11 &amp; 14</td>
<td>Con. 2 South of Talbot Road</td>
<td>Big Creek, Venison Creek</td>
<td>C</td>
<td></td>
<td>Well drained soils with scattered soft maple Areas of marginal land being converted? Stewardship reclamation and habitat restoration? Supported by large coniferous plantation to west</td>
</tr>
<tr>
<td>MI-15</td>
<td>Middleton</td>
<td>MI-15</td>
<td>9</td>
<td>Con. 2 South of Talbot Road</td>
<td>Big Creek, Venison Creek</td>
<td>C</td>
<td></td>
<td>Well drained soils with patches of Walsingham soils Barren and scattered soft maple Most likely an area with wet pockets within woodlot Drain is more on the edge; direct impact by municipal drain?</td>
</tr>
<tr>
<td>MI-26</td>
<td>Middleton</td>
<td>MI-26</td>
<td></td>
<td></td>
<td></td>
<td>C</td>
<td></td>
<td>Area has great potential; good wet soils, concentration of drains and 70% soft maple Located near significant spawning area (Little Otter Extension Drain and Big Marsh Drain) Extend the fisheries rehab project to include this wetland</td>
</tr>
<tr>
<td>MI-22</td>
<td>Middleton</td>
<td>MI-22</td>
<td>170</td>
<td>Talbot Road East South</td>
<td>Big Creek</td>
<td>C</td>
<td>Good soils; poor vegetation community (MS 30%) Drain runs the edge of woodlot except for a small finger impacting only a fraction of the wet area Should be evaluated 1982 OMAFRA data suggest large idle land (low shrub / grass land)</td>
<td></td>
</tr>
<tr>
<td>WI-57</td>
<td>Windham</td>
<td>WI-57</td>
<td>19</td>
<td>12</td>
<td>Big Creek</td>
<td>C</td>
<td></td>
<td>Good location in relation to other wetlands Drainage is located at the edge of the woodlot Soils are wet, but dominated by upland species High density of drainage Size is limiting</td>
</tr>
<tr>
<td>WI-39</td>
<td>Windham</td>
<td>WI-39</td>
<td>17 &amp; 16</td>
<td>1</td>
<td>Big Creek</td>
<td>C</td>
<td></td>
<td>Well drained soils and weakly associated with scattered soft maple Size is limiting If wet, then should consider evaluating and complexing with BC-10 and BC 9</td>
</tr>
<tr>
<td>MI-12</td>
<td>Middleton</td>
<td>MI-12</td>
<td>146</td>
<td>Talbot Road East North</td>
<td>Little Otter</td>
<td>C</td>
<td>1972 BW aerial versus Colour Infra Red shows farmland taken out of production Created a low shrub / marsh type area Stewardship reclamation and habitat restoration? Size is limiting</td>
<td></td>
</tr>
<tr>
<td>WI-13</td>
<td>Windham</td>
<td>WI-13</td>
<td>18</td>
<td>4 &amp; 3</td>
<td>Big Creek</td>
<td>C</td>
<td>Good wet soils; dominant soft maple Drains runs the edge of the woodlot Should be considered for a wetland evaluation</td>
<td></td>
</tr>
<tr>
<td>Wetland ID</td>
<td>Location</td>
<td>Township</td>
<td>Lot</td>
<td>Concession</td>
<td>Watershed</td>
<td>Rank</td>
<td>Status</td>
<td>Recommendation/Comments</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------</td>
<td>----------</td>
<td>-----</td>
<td>------------------</td>
<td>-------------</td>
<td>------</td>
<td>--------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| WI-10     | Windham        | 24       |     | Big Creek        | Big Creek   | C    |        | Wet soils with marginal wetland species
Size is limiting
Contour line suggest that the Municipal Drain is simply a dredging/channelization of the system
Consider for a CFIP fisheries rehabilitation project?                                                                                                                                                      |
| MI-2      | Middleton      | 19 & 20  |     | Con. 2 North Talbot Road | Big Creek   | C    |        | Question has to how much is wetland
Probably just small pockets within the woodlot
Colour Infra-red shows some marginal land out of production low shrub / grassland
Stewardship reclamation and habitat restoration?                                                                                                                                                        |
| MI-25     | Middleton      | 177 & 178|     | Talbot Road East South | Big Creek   | C    |        | Wet soils and dominated by soft maple
Not identified has municipal drain (Private)
A number of ponds suggest wet area; however, farm field located in the middle of woodlot
Stewardship reclamation and habitat restoration?                                                                                                                                                         |
| MI-4      | Middleton      | 14       |     | Con. 3 North Talbot Road | Big Otter Creek | C    |        | Very small area with an irrigation pond already in the area
Colour Infra-red show a small marsh / marginal land in among
Possible D. U. project (just off HWY#3)
Size is limiting                                                                                                                                                                                                 |
| MI-21     | Middleton      | 162, 165 |     | Talbot Road East South | Little Otter |      |        | Flows through the Town of Courtland
Appears to be more of a floodplain area
Municipal Drain has channelized the headwaters of Little Otter Creek (cold water fisheries)
CFIP / Stewardship Project - fisheries rehab. Project to re-naturalize the stream
Community oriented project / education and public awareness benefits                                                                                                                                       |
| MI-32     | Middleton      | 20       |     | Con. 3 South of Talbot Road | Big Creek   |      |        | Contour line suggest that the Municipal Drain is simply a dredging/channelization of the system
Major drainage system occurs upstream (more benefit to focus on restoring upstream)
CFIP / Stewardship Project - fisheries rehab. Project to re-naturalize the stream                                                                                                                                 |

**APPENDIX E - 4**
Landowner and Municipality Contact
Landowner and Municipality Contact

The following steps must be taken to retrieve appropriate landowner information and approval:

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Retrieve Municipal Assessment Map for the Municipal Drain location/drainage watershed</td>
</tr>
<tr>
<td>Step 2</td>
<td>Compile a list of tax roll numbers for landowners who will be involved/affected by restoration tactics</td>
</tr>
<tr>
<td>Step 3</td>
<td>Retrieve landowner names and addresses from Municipal Office (based on tax roll numbers)</td>
</tr>
<tr>
<td>Step 4</td>
<td>Retrieve landowner contact information (telephone numbers) from available sources i.e. internet listings, phone books, and municipal directories.</td>
</tr>
<tr>
<td>Step 5</td>
<td>Contact landowners for permission to access their lands and to discuss options and opinions with regards to the project</td>
</tr>
</tbody>
</table>

Example of Municipal Assessment Map:
Landowner Questionnaire
Wetland Drain Restoration Project

For more information, please contact:
  Dave Richards, Area Biologist, Ministry of Natural Resources  (519) 773-4731
  Peter Bryan-Pulham, Senior Drainage Superintendent, Norfolk County (519) 582-2100 ext. 601
  Shawn Vanacker, Drainage Superintendent, Norfolk County  (519) 582-2100 ext. 602

*******************************************************************************

POTENTIAL RESTORATION SITES - LANDOWNER QUESTIONNAIRE
*******************************************************************************

1. ARE YOU INTERESTED IN HOLDING WATER WITHIN YOUR DRAIN DURING DRY PERIODS?  YES____ NO____

2. DRAIN NAME:__________________________________________________________

3. DRAIN TYPE: (circle one) PRIVATE / AWARD / MUTUAL AGREEMENT / MUNICIPAL

4. IS THE DRAIN PART OF A CREEK?  YES____NO____

   IF YES, CREEK NAME_____________________________________________________

   IF NO, PLEASE EXPLAIN__________________________________________________

5. DOES THE DRAIN INTERCEPT A TREED SWAMP?  YES___ NO____

6. DOES THE DRAIN INTERCEPT A FORESTED AREA?  YES___ NO____

7. IS THE DRAIN BUFFERED?  YES____ NO____

   DESCRIBE_______________________________________________________________

8. WHEN WAS THE DRAIN LAST MAINTAINED? _________________________________

9. HAVE YOU RECENTLY HAD WATER SHORTAGE PROBLEMS? YES____ NO____

   IF YES, PLEASE EXPLAIN________________________________________________

   _______________________________________________________________________

10. AGRICULTURAL PRACTICES - CROPS GROWN: _____________________________

   _______________________________________________________________________

11. FROM WHERE DO YOU CURRENTLY IRRIGATE? (circle one)

     POND / CREEK /井 / OTHER

___________________________________________________________________________
12. DO YOU HAVE ANY CONCERNS/COMMENTS/SUGGESTIONS FOR RESTORATION OPTIONS ON YOUR PROPERTY? ______________________________________

________________________________________________________________________

________________________________________________________________________

13. PROPERTY SIZE:___________________________

WOODLOT SIZE____________________________

% IN CROPS________________________________

14. IS YOUR PROPERTY TILED?  YES____NO____

%TILED ________ SYSTEMATIC ________ RANDOM________

15. LANDOWNER INFORMATION:

NAME:_____________________________________________________________

TELEPHONE NUMBER:______________________________________________

MAILING ADDRESS: ________________________________________________

PROPERTY ADDRESS (911 #):________________________________________

LOT: ______________________ CONCESSION:_____________________

TOWNSHIP:____________________ COUNTY:_________________________

*******************************************************************************

MAP OF PROPERTY:
Field Inventory and Evaluation
# Field Inventory and Evaluation (Guide)

**SITE LOCATION:**

| Wetland Drain Site Identification Code: |  |
| Common Wetland Name: |  |
| PSW: (Name/Score/High score section)/ Unevaluated |  |
| Site Ranking: |  |
| Site Location: (Lot/Conc/Twp/County) |  |
| Nearest Intersection: |  |
| Nearest Urban Centre |  |
| Physiographic Region |  |
| Associated Soils |  |
| Associated Topography |  |

**SITE LOCATION MAP: Attached**

**DRAINAGE INFORMATION:**

| Drain Name |  |
| Date of Construction and Details: |  |
| Extent of Drainage Watershed: (Lot/Conc) |  |
| Drain Gradient: |  |
| Channel Width: |  |
| Bank Height: |  |
| Spoil location: |  |
| Soil composition within drain: |  |

**DRAIN HYDROLOGY:**

| Direction of Flow: |  |
| Drainage Ditch Flow (permanent/ intermittent) |  |
| Water level: |  |
| Receiving body: |  |
| Seeps: |  |
| General Water Quality: |  |
| Water Temperatures (and time): |  |
| Additional Notes: |  |
**ASSESSMENT MAP AND DRAIN PROFILE: Attached**
**PHOTOS: Attached**

**WETLAND HABITAT CHARACTERISTICS:**

| Location of Drain relative to habitat: |
| Surficial soils (and Layer depth): |
| Subsurface soils: |
| Location in local watershed: |
| Headwater/ receiving body: |
| Wetland Size: |
| Wetland Complexity |
| Site Type |
| Wetland Types and Level of Diversity: |
| Dominant Species (Vegetation Communities and Density): |
| Understory Species (Vegetation Communities): |
| Wetland Significance/ functions: |
| Evidence of vernal pooling/swales: |
| Drainage impacts on wetland: |
| Other/ previous impacts by drainage works: |
| Other impacts on wetland: |
| Additional Notes: |
| Evidence of Wildlife: |
| Fish Habitat: |
| Support for fish Habitat: |
| Notes: |

**LOCALIZED SITE MAP: Attached**
**PHOTOS: Attached**

**SURROUNDING LAND USE:**

| Land use designations: |
| Surrounding land uses: |
| Existing tile outlets: |
| Areas for mitigation or concern: |
| Elevation of arable lands in relation to the drain and wetland: |
| Influence of restoration options on arable lands: |
| Additional Notes: |
**PHOTOS: Attached**

**PROPERTY OWNER INPUT:**

<table>
<thead>
<tr>
<th>Landowner:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Views/Comments:</td>
<td></td>
</tr>
<tr>
<td>Benefits:</td>
<td></td>
</tr>
<tr>
<td>Mitigation measures:</td>
<td></td>
</tr>
</tbody>
</table>

**CONCLUSIONS AND RECOMMENDATIONS:**

<table>
<thead>
<tr>
<th>Conclusions:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommendations:</td>
<td></td>
</tr>
<tr>
<td>Proposed Benefits:</td>
<td></td>
</tr>
<tr>
<td>Summary of Landowner views:</td>
<td></td>
</tr>
</tbody>
</table>

**Further Notes:**

<table>
<thead>
<tr>
<th>Areas for mitigation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Other areas</td>
<td></td>
</tr>
</tbody>
</table>

**NEXT STEPS:**

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Municipality Memorandum
MEMORANDUM

Date: July 25, 2002

To: Affected Landowner’s Adjacent to the Zebra Drain

From: The Norfolk County Drainage Division

Subject: Hiring an engineer to make alterations to the Zebra Drain

In August of 2001 the Ministry of Natural Resources, Norfolk Land Stewardship Council and Norfolk County initiated a feasibility study to investigate the potential for water retention and control in the Zebra Drain. The main purpose of this study was to determine if the municipal drain could serve a dual purpose; to provide drainage to the surrounding areas when required and to hold back water within the drain during drier periods in order to replenish the ground water table.

The feasibility study has proven that water can be held back in the Zebra Drain and the surrounding wetland area with the implementation of one or more adjustable water control structures. The feasibility study determined that water can be held back in the drain and surrounding wetland without affecting the surrounding agricultural land, as this is a major concern of farmers in the area.

At this point in time the Drainage Division is seeking landowner support in the decision to recommend to the Norfolk County Council that an engineer be hired under Section 78(1) of the Drainage Act to make alterations to the Zebra Drain. These proposed alterations must take place under a new engineer’s report and would consist of designing and implementing one or more adjustable water control structures within the drain.

Alternative funding sources have been utilized in order to complete the feasibility study and to get the proposed engineer’s report initiated so there are no costs to the landowners. In regards to how the balance of the project will be paid for, landowner’s can rest assured that the Ministry of Natural Resources and the Norfolk County Drainage Division feel that they can obtain enough funding to support the cost of the entire project. In the event that we cannot obtain enough funding to cover the total project costs, some monies may be assessed to the landowners. However before costs are assessed to any landowners we will be notifying them as to what their assessed costs would be and whether or not they would like to proceed with the project at that expense.

This is a worthwhile project as in recent years it has been realized that the quantity and quality of our water supply may not be as abundant as we originally thought. This project will help to replenish the ground water table and
improve habitat in the area surrounding the Zebra Drain, as a similar projects have been undertaken elsewhere in Norfolk County and have proven to be successful.

Yours truly,

Shawn G. Vanacker
Drainage Superintendent

c.c. Dave Richards
Long Point Area Biologist
Ministry of Natural Resources
Aylmer District

c.c. David J. Reid
Stewardship Coordinator
Norfolk Land Stewardship Council
OMAFRA

As an affected landowner on the Zebra Drain by signing below I am stating that I agree with the Norfolk County Drainage Division’s decision to proceed with hiring an engineer under Section 78(1) of the Drainage Act to make alterations to the existing Zebra Drain. I also understand that the Ministry of Natural Resources and the Norfolk County Drainage Division feel that they can obtain enough funding to support the entire project costs. If enough funding cannot be obtained to cover the entire project costs I will expect to be notified as to my proposed assessed costs to continue with the project and then have the availability to decide whether or not I would like to proceed at that expense.

__________________________________________  ______________
John Smith      Date

__________________________________________  ______________
Jane Doe      Date
Sample Water Control Structure Designs
**GENERAL NOTES**

© MAINTENANCE TO BE DONE BY TOWNSHIP FORCES.

WITHDRAWAL AVAILABLE TO THE CONTRACTOR TO CONSTRUCT THE NEW DRAINS IT OF THESE LANDS IMMEDIATELY ADJACENT TO THE DRAIN AND ALONG SHALL NOT EXCEED AN AVERAGE WIDTH OF 20 METERS. THE WIDTH SHALL BE 10 METERS FOR PURPOSES OF FUTURE MAINTENANCE.

ALONG THE COURSE OF THE DRAIN SHALL MAKE AN ACCESS ROUTE WIDTH ROAD TO THE DRAIN LOCATION AVAILABLE TO THE CONTRACTOR. THE WIDTH OF THIS ROUTE SHALL NOT EXCEED 8 METERS. THE ACCESS ALSO APPLY FOR FUTURE MAINTENANCE PURPOSES.

GET OF LOSS UNDER THIS WORK IS TO BE DONE BY THE TOWNSHIP MUS BY VARIOUS AGENCIES FOR URBAN AND WILDLIFE CONSERVATION.

The maintenance of these works are to be assessed in accordance with

By John J. Dodds, O.L.B. DATED JANUARY 19, 1968.
SIDE ELEVATION

SCALE: 1cm=0.25m (1:25)

WATER CONTROL STRUCTURE STA. 0+423

END ELEVATION

SCALE: 1cm=0.25m (1:25)

GARNHAM DRAIN
NORFOLK COUNTY

SPRIET ASSOCIATES
LONDON
CONSULTING ENGINEERS

115 YORK STREET — LONDON
(519) 672-4100 — HX1 1AD
Boat winch or wheel mechanism

CSP collar allows for connection to existing or new pipe.

Safety Platform

Weir Opening

Stream Bottom
Sump / Pool

Elevation determined from survey

Elevation to be determined from survey

storage

Adjustable gate allows for bottom draw. Opening size depends on flow and fish migration.

Anchor plates

Dimensions
1) Pipe dia. for collar is determined by survey
2) Width (a) of structure is equals the pipe dia + 0.3m. b = a

Notes:

Design Considerations
Sump should be designed so as to create shallow pool for fish migration as well as providing a cleanout.

Structure must be weighted down and backfilled properly.
The gate opening should sized to allow full flow through pipe. The weir opening should be sized to allow full flow through the pipe.
Grated top platform allows for water access in the event of a obstruction in the weir as well as a safety platform to operate the gate.
The maximum storage height is determined by survey to ensure no upstream damage or upstream outlets are effected.

Consideration should be given to the storm event of the immediate down stream culvert
An anti-seepage collar should be considered especially if structure is operated within the same year as the installation.
HORIZONTAL CHAINAGE (METERS)
DYKE PROFILE

LIST OF MATERIALS

- SAFETY GRATING - TO BE PLACED TO ELEVATION DETAILED ON CONTRACT DRAWINGS
- TOP OF HALF ROUND DROP INLET STRUCTURE
- SECTION VIEW OF SAFETY GRATE AND BAILING

QUANTITIES

LUMP SUM CONTRACT

EARTHWORK:
CONCRETE:
RIP RAP:
GRAVEL:
REINFORCING STEEL (16mm):

NOTES

1) APPROVED NATIVE BACKFILL TO BE USED FOR DYKE CONSTRUCTION.
2) PIPE BEDDING TO BE GRANULAR "A" AND COMPACTED IN 300mm LUNTS AROUND THE PIPE AS DIRECTED BY THE ENGINEER.
3) PIPE BACKFILL TO BE HARD PACKED UNDER HAUNCHES OF PIPE.
4) A 100mm LAYER OF NATIVE CLAY MATERIAL TO BE USED AS A SEAL ON THE UPSTREAM FACE OF DYKE AT CONTROL.
5) ALL WELDED JOINTS, CHANNELS, ANGLES; SAFETY GRATE TO BE PAINTED WITH TWO COATS OF RUSTPROOF PREVENTATIVE PAINT.
6) ALL BORROW AREAS TO BE SLOPED AND GRADED, RETOPSOILED AND SEEDED.
7) PLACE 75mm MIN. TOPSOIL ON DYKE, PLACE GRASS SEED AS PER SPECIFICATIONS.

Ducks Unlimited Canada
SKETCH OF

DRAWN BY
PROJECT NO.
SHEET...
Agri Drain Inline Water Level Control Structure™

- Rugged ½" PVC structure.
- Heavy steel lockable top.
- Stainless steel screws and custom anodized aluminum corner extrusions used for strength and durability.
- 5' & 7' Stoplogs for adjustability.
- Flexible couplers allow PVC, plastic pipe, or other materials to be easily attached.

(Please specify type of pipe when ordering
- 5-Year Warranty on all parts.

Please allow up to 2 weeks for shipment.

Handle (included) is used to install and remove stoplogs.

Rubber seal assures a tight fit to prevent leakage.

Durable stainless steel lifting hooks.

Aluminum extruded corners with stainless steel screws.

Flexible, rubber connectors with heavy duty stainless steel clamps.

"Larger CMP structures also available—see page 7.
Call for details on custom sizes and pricing.

### INLINE WATER LEVEL CONTROL STRUCTURE

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Inside Dim.</th>
<th>Height 2'</th>
<th>Height 3'</th>
<th>Height 4'</th>
<th>Height 5'</th>
<th>Height 6'</th>
<th>Height 7'</th>
<th>Height 8'</th>
<th>Height 9'</th>
<th>Height 10'</th>
<th>Height 11'</th>
<th>Height 12'</th>
<th>Height 13'</th>
<th>Height 14'</th>
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<tbody>
<tr>
<td>4&quot;</td>
<td>8' x 10'</td>
<td>$290</td>
<td>$310</td>
<td>$335</td>
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<td>8' x 10'</td>
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<td>14' x 16'</td>
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<td>$565</td>
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<td>$640</td>
<td>$680</td>
<td>$720</td>
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<td>$800</td>
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<td>24&quot;**</td>
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<td>$2615</td>
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</table>

*To fit 24" dual wall polyethylene pipe*
Improving Water Quantity

Improving Water Quality