

FEASIBILITY STUDY – RAW WATER FOR AGRICULTURAL IRRIGATION PURPOSES

PROJECT REPORT

Prepared for:

Regional Municipality of Niagara
Planning and Development Department
3550 Schmon Parkway
P.O. Box 1042
Thorold, Ontario L2V 4T7

Prepared by:

Stantec Consulting Ltd.
49 Frederick Street
Kitchener, ON N2H 6M7

In association with:

J. Kinkead Consulting
1828 Melody Drive
Mississauga, ON L5M 2K8

and

KCMS Applied Research and Consulting Inc.
5 Park Road North
Grimsby Ontario L3M 2P2

1611 10501
August 2005

FEASIBILITY STUDY – RAW WATER FOR AGRICULTURAL IRRIGATION PURPOSES PROJECT REPORT

Executive Summary

Background and Purpose

Agriculture is one of the most important industries in the Niagara Region, generating economic revenues estimated at 1.8 billion dollars per year. Providing irrigation infrastructure has been identified as a strategy to support the tender fruit, grape, greenhouse, and nursery productions in the northern part of the Region. The Region of Niagara has retained Stantec Consulting Ltd. to undertake a feasibility study for providing raw water for agricultural irrigation purposes.

The overall objective of this study was “to provide a single or a range of options for providing raw water to the agricultural community in a manner that is technical feasible, financially responsible, environmentally sustainable, and based on a workable and cost effective management.”¹

Existing Conditions

There are currently some 23,000 acres of land used for tender fruit, grape, greenhouse, and nursery productions in the five municipalities of Niagara-on-the-Lake, St. Catharines, Lincoln, Grimsby, and Pelham. However, the good tender fruit or grape land areas extend over 55,000 acres. There is, therefore, significant room for the expansion of high value crop production in the region.

A significant portion of tender fruit growers and some grape growers currently use irrigation, especially in areas below the Escarpment.

The Region is in an enviable position in terms of availability of water resources. Niagara-on-the-Lake is practically surrounded by water, providing various existing and potential irrigation supply sources. The area below the Escarpment is fairly close to Lake Ontario, and can conceivably use the lake for supplying an irrigation system. A large hydro diversion from the Welland Canal is discharged into Twelve Mile Creek, providing substantial flow on the west side of St. Catharines. The areas above the Escarpment may have access to good groundwater. Various streams pass through the region, and substantial rainfall during the spring provides opportunity for the storage of water and utilization during the summer irrigation season.

The region is also rich in natural and ecological resources. These include several ANSIs, woodlots, wetlands, and streams. Water taking and the construction of a major irrigation infrastructure may potentially impact these important resources.

¹ Regional Municipality of Niagara, Terms of Reference – Feasibility of Providing Raw Water for Agricultural Irrigation Purposes in Niagara, September 2004.

Irrigation Demands

Based on the available data, the peak irrigation demand of the region was estimated at 480,000 cubic meters per day (87,000 US gallon per minute or 4,600 acre-inches per day). The average annual irrigation demand of the Region was estimated at 13 million cubic meters (3.6 Billion US gallon or 11,000 acre-feet).

Irrigation Districts

Based on the locations of the different clusters of potential irrigation lands, the following irrigation districts were identified²:

- East Irrigation District – Niagara-on-the-Lake
- West Irrigation District – Grimsby, Lincoln and St. Catharines. Due to substantial elevation differences within this area, this district was subdivided into two zones:
 - Zone A: below the Escarpment
 - Zone B: above the Escarpment
- South District – Pelham

Permits and Approvals

Any proposed undertaking to supply irrigation water for agricultural purposes will involve a number of provincial and federal permits and approvals. The most fundamental and potentially most challenging of these is likely to be the approval to “take water” (Permit to Take Water). The application for the permit must satisfy a number of tests relating to the purpose and magnitude of the withdrawal, availability of supply, the prevention or minimization of impacts on other water users and the environment, and the demonstration that best management practices will be implemented in the conservation and use of the water.

In considering source options, larger watercourses offer greater certainty (than smaller supply sources) that the level of taking is not likely to interfere with other interests. Similarly taking of water during periods of higher flow can prevent or lessen impacts on the environment and other users.

The Great Lakes Charter and the Niagara Treaty are other key source selection and approval considerations. Source options that do not result in an intra-basin diversion of water and that avoid other issues relating to the bi-national sharing of water would involve less complexity.

² Irrigation “districts” are areas of irrigated lands that due to their geographical, political, or other characteristics can be irrigated by a common supply system.

Alternatives and Short-Listing

Two sets of alternatives were considered:

- **Source Alternatives:** These alternatives were Municipal Treated Water, Municipal Treated Wastewater, Welland Canal, Lake Gibson/Lake Moodie, Twelve Mile Creek, Queenston Reservoir, Outlet of OPG Tunnels, Niagara River, Lake Ontario (including Jordan Harbour), Groundwater, Supply from Off-Stream Reservoirs, and Other Surface Streams.
- **Distribution Alternatives:** The general distribution alternatives considered were pipeline distribution and open channel (ditch) distribution.

The source alternatives underwent an initial short-listing based on their applicability to each district/zone. They were then combined with distribution alternatives, if applicable, to form complete infrastructure alternatives. These were further analyzed based on their financial and non-financial implications.

General Conclusions

The study reached the following general conclusions:

- There is significant room for growth of high value crops in the Region. Difficulties in access to irrigation water may be preventing the expansion of high value agricultural production into the remaining suitable areas of the region.
- The ideal regional irrigation infrastructure will have an initial cost of approximately 100 million dollars. The cost, however, can be reduced to approximately 40 million dollars using open channel distribution (i.e. using the existing municipal drainage ditches)³.
- Any regional irrigation project is likely to require substantial financial support from the government.

Recommended Infrastructure for West District – Zone A

- The servicing of the irrigation areas of Zone A by two systems, one servicing the East side and one servicing the West side, is recommended due to its cost advantage.
- The recommended infrastructure will depend on the available funds for the irrigation project, as follows:

³ The financial figures stated in this report are based on limited data and may change once the actual size and locations of the service area are further examined.

- If funding of \$45 million is available, we recommend two pipeline distribution system. There are five potential sources for the East System (Lake Moodie, Twelve Mile Creek, Welland Canal, Lake Ontario or Jordan Harbour). The costs of these alternative sources appear to be comparable, while they differ in their non-financial implications. The final choice between these alternative sources will require further investigations and consultations. The recommended source for the West System is Lake Ontario.
- If available funding is limited to approximately \$30 to 35 million, we recommend a pipeline distribution system for the West side with an intake in Lake Ontario and an open channel distribution system for the East Side supplied from Lake Moodie or Twelve Mile Creek.
- If available funding is substantially less than \$30 million a centralized irrigation supply and distribution system would become unfeasible. Low cost solutions may be available for irrigating the lands that are close to major water sources (Twelve Mile Creek or Lake Ontario). A program of assistance to construct Off Stream Reservoirs may be provided; however, due to the limited funding, this may be adopted by only a small percentage of the growers who are able to self-finance a substantial portion of the costs.
- Supply from off-stream reservoirs can be used as a solution to reduce the cost of the regional infrastructure where ponds already exist or for small isolated irrigation areas. These possibilities will need to be investigated in more detail in order to finalize the optimum combination of the alternatives, and take advantage of the existing infrastructure.

Recommended Infrastructure for West District – Zone B

- The recommended alternative is Supply from Groundwater Wells, conditional upon the results of a groundwater study.
- If the groundwater study does not support the adoption of this alternative, Supply from Off-Stream Reservoirs would become the recommended alternative. However, even a partial contribution from groundwater wells will substantially reduce the cost of the off-stream reservoirs.

Recommended Infrastructure for East District

- The recommended infrastructure for the East Irrigation District will depend on the available funds for the irrigation project, as follows:
 - If funding of \$45 million is available, we recommend the replacement of the existing irrigation system with a pipeline distribution system with supplies from the Welland Canal – upstream of Lock 2 or Niagara River, or a combination of the two.

- If available funding is limited to approximately \$20 million, we recommend full servicing of the existing open channel irrigation distribution network using a gravity feeder pipeline. The source of the system can be the Welland Canal – upstream of Lock 3 or 6, or the outlet of OPG Tunnels. The selected source will replace the existing supply sources.
- If available funding is limited to approximately \$6 million, we recommend the construction of a gravity feeder pipeline to extend irrigation servicing to the south-west area of the NOTL. The source of the gravity pipeline can be the Welland Canal – upstream of Lock 3 or 6, or the outlet of OPG Tunnels. In addition to the construction of the new gravity main, certain improvements in the existing systems should be implemented if one of these alternatives is selected.

Recommended Infrastructure for South District

- The recommended alternative is Supply from Groundwater Wells, conditional upon the results of a groundwater study.
- If the groundwater study does not support the adoption of this alternative, Supply from Off-Stream Reservoirs would become the recommended alternative. However, even a partial contribution from groundwater wells will substantially reduce the cost of the off-stream reservoirs.

Management of Irrigation Systems

- The recommended management system for each irrigation district at this point is management by municipal authorities, similar to the existing management structure of the Niagara-on-the-Lake system. An overall entity, likely within the Regional Municipality of Niagara, would be desirable to coordinate the work of the different irrigation districts and promote their common interests in areas such as financial and technical support.
- On-farm management of the irrigation systems will require a move toward accepted methods of irrigation scheduling. This will require an educational program prior to the construction phase, and possibly more irrigation research specific to the Region.

Financing

- National Water Supply Extension Program (NWSEP) is expected to be launched in Ontario shortly. This program may be a source of financing for some of the subsequent studies required for this project, for the on-farm irrigation infrastructure recommended for the areas above the Escarpment, and for the improvements to the existing component of the Niagara-on-the-Lake Irrigation System.

- Funding for a complete regional irrigation infrastructure does not exist at the present time and will need to be planned at senior government levels.

Recommended Next Steps

The following are the recommended next steps to follow up on this preliminary study:

1. Initiation of Discussion on Financing: Discussion on the level of support from the government and the farmers' ability to pay should be initiated immediately.
2. Field Study: A field study is required to fill the data gaps encountered during this feasibility study. A relatively detailed layout of the potential irrigated lands and improved demand estimates will provide sufficient data to finalize the layouts of the different transmission and distribution alternatives as well as cost estimates.
3. Groundwater Study: A groundwater study is needed to determine the potential supply capacities of aquifers under the irrigation areas of South District and West District - Zone B (areas above the Escarpment).
4. Completion of Class Environmental Assessment Phase 2: This step will include the following additional tasks:
 - a. Further Consultations:
 - i. with different levels of government regarding permit requirements.
 - ii. with growers regarding their participation in the project and their ability to pay for the irrigation service.
 - iii. with other major stakeholders, such as OPG, St. Lawrence Seaway Authority, and CN Rail regarding various alternatives that may require their approvals.
 - b. Analysis of the impacts of different alternatives on the natural and social environments.
 - c. Evaluation of short-listed alternatives using the above data and preparation of proposed Preferred Alternatives for discussion with stakeholders.
 - d. Public Information Centres.
 - e. Selection of Preferred Alternatives.

Feasibility Study – Raw Water for Agricultural Irrigation Purposes Project Report

Table of Contents

EXECUTIVE SUMMARY	E.1
--------------------------------	------------

1.0 INTRODUCTION	1.1
1.1 GENERAL	1.1
1.2 PURPOSE OF THIS REPORT	1.1
1.3 SCOPE OF PROJECT	1.1
1.4 STUDY METHODOLOGY	1.2

2.0 EXISTING CONDITIONS.....	2.1
2.1 EXISTING IRRIGATION PRACTICES AND SKILLS	2.1
2.1.1 Tender Fruit and Grape Growers	2.1
2.1.2 Greenhouses	2.2
2.2 EXISTING IRRIGATION INFRASTRUCTURE	2.3
2.2.1 Niagara-on-the-Lake Irrigation System	2.3
2.2.2 Other Irrigation Infrastructure	2.4
2.3 OTHER RELATED INFRASTRUCTURE	2.4
2.3.1 Municipal Water and Wastewater Infrastructure	2.4
2.3.2 Ontario Power Generation Facilities and Welland Canal	2.6
2.4 NATURAL ENVIRONMENT	2.8
2.4.1 Existing Water Sources	2.8
2.4.2 Designated Natural Environmental Areas	2.9
2.5 SOCIOECONOMIC ENVIRONMENT	2.13

3.0 IRRIGATION DEMANDS.....	3.1
3.1 PEAK DEMANDS PER ACRE	3.1
3.1.1 General	3.1
3.1.2 Peak Demand for Tender Fruits and Grapes Based on Existing Irrigation Practices	3.1
3.1.3 Theoretical Peak Demands for Tender Fruits and Grapes	3.1
3.1.4 Peak Demand for Greenhouses	3.5
3.1.5 Peak Demands for Nurseries	3.5
3.1.6 Summary of Unit Irrigation Demands	3.5
3.2 SEASONAL DEMANDS	3.6
3.3 REGIONAL IRRIGATION DEMANDS	3.9
3.3.1 Proposed Irrigation Districts	3.9
3.3.2 Peak Regional Demand	3.11
3.3.3 Seasonal Regional Demand	3.12

4.0 REVIEW OF EXISTING IRRIGATION MODELS	4.1
4.1 GENERAL.....	4.1
4.2 NIAGARA-ON-THE-LAKE MUNICIPAL IRRIGATION SYSTEM	4.3
4.2.1 System Description	4.3
4.2.2 System Management	4.5
4.2.3 Lessons from NOTL Irrigation System	4.5
4.3 NORFOLK WATER SUPPLY ENHANCEMENT PROJECT (WSEP)	4.6
4.3.1 Project Description	4.6
4.3.2 Project Implementation and Management	4.7
4.3.3 Lessons from Norfolk WSEP	4.8
4.4 PROPOSED LEAMINGTON AREA DRIP IRRIGATION PROJECT	4.9
4.4.1 Description of the Proposed Irrigation System	4.9
4.4.2 Proposed System Management	4.10
4.4.3 Lessons from the Leamington Feasibility Study	4.10
4.5 AGASSIZ RESOURCE MANAGEMENT (ARM) LTD., WINKLER, MB	4.11
4.5.1 Project Description	4.11
4.5.2 System Management	4.13
4.5.3 Lessons from ARM	4.13
4.6 SAN CARLOS AND HOHOKAM IRRIGATION & DRAINAGE DISTRICTS, COOLIDGE, ARIZONA	4.14
4.6.1 Project Description	4.14
4.6.2 System Management	4.17
4.6.3 Lessons from San Carlos and Hohokam Irrigation & Drainage Districts	4.18
4.7 CONCLUSIONS	4.18

5.0 WATER RELATED PERMITS AND APPROVALS.....	5.1
5.1 GENERAL	5.1
5.2 PROVINCIAL APPROVALS	5.1
5.2.1 Conservation Authorities Act, Ministry of Natural Resources (MNR)	5.1
5.2.2 Environmental Assessment Act, Ministry of the Environment (MOE)	5.2
5.2.3 Greenbelt Act and Greenbelt Plan, Ministry of Municipal Affairs and Housing (MMAH)	5.2
5.2.4 Lakes and Rivers Improvement Act (MNR)	5.4
5.2.5 Niagara Escarpment Planning and Development Act (MNR)	5.4
5.2.6 Ontario Water Resources Act (MOE)	5.4
5.2.7 Public Lands Act (MNR)	5.5
5.2.8 Municipal Act (MMAH)	5.6
5.2.9 Other Provincial Approvals	5.6
5.3 FEDERAL APPROVALS	5.6
5.3.1 Canadian Environmental Assessment Act (CEAA), Environment Canada (EC)	5.6
5.3.2 Fisheries Act, Department of Fisheries & Oceans (DFO)	5.7
5.3.3 Navigable Waters Protection Act, Transport Canada (TC)	5.7
5.4 GREAT LAKES CHARTER	5.7
5.4.1 Great Lakes Charter (1985)	5.7
5.4.2 Great Lakes Charter Annex (June 2001)	5.8
5.4.3 Status of GLC Annex Commitments	5.8

5.5 NIAGARA TREATY.....	5.10
5.6 SUMMARY.....	5.11

6.0 ALTERNATIVE IRRIGATION INFRASTRUCTURES FOR NIAGARA REGION.....	6.1
6.1 GENERAL.....	6.1
6.2 SOURCE ALTERNATIVES.....	6.1
6.3 DISTRIBUTION ALTERNATIVES.....	6.2

7.0 SCREENING LONG LIST OF SOURCE ALTERNATIVES	7.1
7.1 ALTERNATIVE 1 - MUNICIPAL TREATED WATER.....	7.1
7.2 ALTERNATIVE 2 - MUNICIPAL TREATED WASTEWATER	7.2
7.3 ALTERNATIVE 3 - WELLAND CANAL	7.3
7.4 ALTERNATIVE 4 - LAKE GIBSON/LAKE MOODIE	7.3
7.5 ALTERNATIVE 5 - TWELVE MILE CREEK.....	7.4
7.6 ALTERNATIVE 6 - QUEENSTON RESERVOIR	7.4
7.7 ALTERNATIVE 7 - OUTLET OF OPG TUNNELS	7.5
7.8 ALTERNATIVE 8 - NIAGARA RIVER	7.5
7.9 ALTERNATIVE 9 - LAKE ONTARIO.....	7.6
7.10ALTERNATIVE 10 - GROUNDWATER	7.6
7.11ALTERNATIVE 11 - SUPPLY FROM OFF-STREAM RESERVOIRS	7.6
7.12ALTERNATIVE 12 - OTHER SURFACE STREAMS	7.7
7.13SPECIAL CONSIDERATION OF ZONE B ALTERNATIVES	7.8
7.14SHORT-LISTED SOURCE ALTERNATIVES	7.9

8.0 ANALYSIS OF INFRASTRUCTURE ALTERNATIVES FOR WEST IRRIGATION DISTRICT – ZONE A	8.1
8.1 SHORT-LISTED SOURCE ALTERNATIVES	8.1
8.1.1 ALTERNATIVE 3: SUPPLY FROM WELLAND CANAL	8.1
8.1.2 ALTERNATIVE 4: SUPPLY FROM LAKE GIBSON / LAKE MOODIE.....	8.2
8.1.3 ALTERNATIVE 5: SUPPLY FROM TWELVE MILE CREEK	8.7
8.1.4 ALTERNATIVE 9: SUPPLY FROM LAKE ONTARIO	8.10
8.1.5 ALTERNATIVE 11: SUPPLY FROM OFF-STREAM RESERVOIRS.....	8.15
8.2 DISTRIBUTION ALTERNATIVES.....	8.16
8.2.1 PIPELINE DISTRIBUTION	8.16
8.2.2 OPEN CHANNEL DISTRIBUTION	8.17
8.3 DISCUSSION OF PROBABLE COSTS.....	8.19

9.0 ANALYSIS OF INFRASTRUCTURE ALTERNATIVES FOR WEST IRRIGATION DISTRICT – ZONE B	9.1
9.1 SHORT-LISTED SOURCE ALTERNATIVES	9.1
9.1.1 ALTERNATIVES 9: SUPPLY FROM LAKE ONTARIO VIA ZONE A DISTRIBUTION SYSTEM.....	9.1
9.1.2 ALTERNATIVE 10: SUPPLY FROM GROUNDWATER WELLS	9.2
9.1.3 ALTERNATIVE 11: SUPPLY FROM OFF-STREAM RESERVOIRS.....	9.4
9.2 DISCUSSION OF PROBABLE COSTS.....	9.5

10.0 ANALYSIS OF INFRASTRUCTURE ALTERNATIVES FOR EAST IRRIGATION	
DISTRICT	10.1
10.1 GENERAL APPROACH.....	10.1
10.1.1 UPGRADE AND EXPAND THE EXISTING IRRIGATION SYSTEM (OPEN CHANNEL DISTRIBUTION)	10.1
10.1.2 CONSTRUCT A NEW IRRIGATION SYSTEM (PIPELINE DISTRIBUTION)....	10.3
10.2 ALTERNATIVES FOR EXPANSION OF EXISTING OPEN CHANNEL SYSTEM	10.5
10.2.1 ALTERNATIVES 3A & 3B: EXISTING SYSTEM WITH ADDITIONAL SUPPLY FROM WELLAND CANAL UPSTREAM OF LOCK 3	10.5
10.2.2 ALTERNATIVES 3C & 3D: EXISTING SYSTEM WITH ADDITIONAL SUPPLY FROM WELLAND CANAL UPSTREAM OF LOCK 6	10.6
10.2.3 ALTERNATIVES 7A & 7B: EXISTING SYSTEM WITH ADDITIONAL SUPPLY FROM OUTLET OF OPG TUNNELS	10.12
10.3 ALTERNATIVES FOR NEW PIPELINE DISTRIBUTION SYSTEM.....	10.13
10.3.1 ALTERNATIVE 3E: PIPELINE SYSTEM WITH SUPPLY FROM WELLAND CANAL UPSTREAM OF LOCK 2	10.13
10.3.2 ALTERNATIVE 3F: PIPELINE SYSTEM WITH SUPPLY FROM WELLAND CANAL UPSTREAM OF LOCK 6	10.16
10.3.3 ALTERNATIVE 7C: PIPELINE SYSTEM WITH SUPPLY FROM OUTLET OF OPG TUNNELS	10.19
10.3.4 ALTERNATIVE 8: PIPELINE SYSTEM WITH SUPPLY FROM NIAGARA RIVER.....	10.19
10.3.5 ALTERNATIVE 9: PIPELINE SYSTEM WITH SUPPLY FROM LAKE ONTARIO.....	10.19
10.4 DISCUSSION OF PROBABLE COSTS	10.23

11.0 ANALYSIS OF INFRASTRUCTURE ALTERNATIVES FOR SOUTH IRRIGATION	
DISTRICT	11.1
11.1 SHORT-LISTED SOURCE ALTERNATIVES	11.1
11.1.1 ALTERNATIVES 3: SUPPLY FROM WELLAND CANAL	11.1
11.1.2 ALTERNATIVE 10: SUPPLY FROM GROUNDWATER WELLS	11.2
11.1.3 ALTERNATIVE 11: SUPPLY FROM OFF-STREAM RESERVOIRS.....	11.4
11.2 DISCUSSION OF PROBABLE COSTS	11.5

12.0 MANAGEMENT OF IRRIGATION SYSTEMS	12.1
12.1 MANAGEMENT OF IRRIGATION DISTRICTS	12.1
12.2 ON-FARM WATER MANAGEMENT PRACTICES.....	12.2

13.0 FINANCING OPTIONS FOR IRRIGATION INFRASTRUCTURE	13.1
---	-------------

14.0 CONCLUSIONS	14.1
-------------------------------	-------------

15.0RECOMMENDED NEXT STEPS.....	15.1
15.1INITIATION OF DISCUSSIONS ON FINANCING	15.1
15.2FIELD STUDY.....	15.1
15.3GROUND WATER STUDY.....	15.2
15.4COMPLETION OF CLASS ENVIRONMENTAL ASSESSMENT PHASE 2.....	15.2
15.5REGULATORY STEPS / PERMITS	15.3
15.5.1 Introduction	15.3
15.5.2 Outstanding Policy Issues Impacting on Source Selection.....	15.3
15.5.3 Links to Greenbelt Protection and Source Protection	15.4
15.5.4 Suggested Next Steps	15.4

16.0REFERENCES & ACKNOWLEDGEMENTS	16.1
16.1REFERENCES	16.1
16.2ACKNOWLEDGEMENTS	16.2

List of Appendices

Appendix A	Layout of NOTL Municipal Irrigation System
Appendix B	Comment from St. Lawrence Seaway Authority on this Report

List of Figures

Figure 1-1:	Study Area	1.4
Figure 2-1:	Municipal Water and Wastewater Treatment Plants in Niagara Region	2.5
Figure 2-2:	Flow Routes from Lake Erie to Lake Ontario	2.7
Figure 2-3:	Fish Habitat Classifications in Water Streams	2.11
Figure 2-4:	Niagara Escarpment Plan Area	2.12
Figure 2-5:	Environmentally Sensitive Areas	2.14
Figure 3-1:	Proposed Irrigation Districts.....	3.10
Figure 4-1:	Locations of the Reviewed Irrigation Projects.....	4.2
Figure 4-2:	Typical Drainage/Irrigation Ditch in NOTL	4.4
Figure 4-3:	Partial Plan of Agassiz Resource Management Ltd (ARM) Infrastructure and Service Area	4.12
Figure 4-4:	Map of San Carlos and Hohokam Irrigation & Drainage Districts	4.16
Figure 8-1	West District Zone A - Alternative 3A: Supply from Welland Canal with Pipeline Distribution	8.3
Figure 8-2	West District Zone A - Alternative 3B: Supply from Welland Canal with Open Channel Distribution	8.4
Figure 8-3	West District Zone A - Alternative 4A: Supply from Lake Gibson / Lake Moodie with Pipeline Distribution	8.5
Figure 8-4	West District Zone A - Alternative 4B: Supply from Lake Gibson / Lake Moodie with Open Channel Distribution	8.6
Figure 8-5	West District Zone A - Alternative 5A: Supply from Twelve Mile Creek with Pipeline Distribution	8.8
Figure 8-6	West District Zone A - Alternative 5B: Supply from Twelve Mile Creek with Open Channel Distribution	8.9
Figure 8-7	West District Zone A - Alternative 9A: Supply from Lake Ontario with Pipeline Distribution	8.11
Figure 8-8	West District Zone A - Alternative 9B: Supply from Lake Ontario with Open Channel Distribution	8.12
Figure 8-9	West District Zone A - Alternative 9C: Supply from Jordan Harbour with Pipeline Distribution	8.13
Figure 8-10	West District Zone A - Alternative 9D: Supply from Jordan Harbour with Open Channel Distribution	8.14
Figure 9-1	West District Zone B - Alternative 9: Supply from Lake Ontario via Zone A Distribution System	9.3
Figure 10-1	East District - Alternative 3A: Existing System with Full Supply from Welland Canal upstream of Lock 3	10.7
Figure 10-2	East District - Alternative 3B: Existing System with Limited Additional Supply from Welland Canal upstream of Lock 3	10.8
Figure 10-3	East District - Alternative 3C: Existing System with Full Supply from Welland Canal upstream of Lock 6	10.10
Figure 10-4	East District - Alternative 3D: Existing System with Limited Additional Supply from Welland Canal upstream of Lock 6	10.11
Figure 10-5	East District - Alternative 7A: Existing System with Full Supply from Outlet of OPG Tunnels.....	10.14

Figure 10-6	East District - Alternative 7B: Existing System with Limited Additional Supply from Outlet of OPG Tunnels	10.15
Figure 10-7	East District - Alternative 3E: Pipeline System with Supply from Welland Canal upstream of Lock 2	10.17
Figure 10-8	East District - Alternative 3F: Pipeline System with Supply from Welland Canal upstream of Lock 6	10.18
Figure 10-9	East District - Alternative 7C: Pipeline System with Supply from Outlet of OPG Tunnels.....	10.20
Figure 10-10	East District - Alternative 8: Pipeline System with Supply from Niagara River...	10.21
Figure 10-11	East District - Alternative 9: Pipeline System with Supply from Lake Ontario	10.22
Figure 11-1	South District - Alternative 3: Supply from Welland Canal	11.3
Figure 14-1	West District Zone A – Two Pipeline Distribution System Solution	14.5
Figure 14-2	West District Zone A – Combined Distribution Solution	14.6

List of Tables

Table 3-1:	Average Daily Water Use for Tender Fruits and Grapes	3.2
Table 3-2:	Average Monthly Water Use and Rainfalls for Tender Fruits and Grapes	3.3
Table 3-3:	Average Calculated Water Deficit for Tender Fruits and Grapes.....	3.3
Table 3-4:	Ranges in Available Water Capacity and Intake Rate for Various Soil Textures	3.4
Table 3-5:	Peak Day Demands (mm/d).....	3.6
Table 3-6:	Drought Calculated Water Deficit for Fruits and Grapes in Niagara Region	3.7
Table 3-7:	Annual Irrigation Demands (mm/year)	3.8
Table 3-8:	Areas of Potential Irrigation District Lands in the Niagara Region (acres).....	3.11
Table 3-9:	Estimated Regional and District Peak Day Demands	3.11
Table 3-10:	Estimated Regional and District Average Annual Irrigation Demands	3.12
Table 7-1:	Screening of Long-Listed Source Alternatives.....	7.9
Table 8-1:	Costs of Regional Infrastructure Alternatives for West Irrigation District Zone A (Million Dollars)	8.20
Table 8-2:	Costs of Regional Infrastructure Alternatives for West Irrigation District Zone A - East Side (Million Dollars)	8.22
Table 8-3:	Costs of Regional Infrastructure Alternatives for West Irrigation District Zone A - West Side (Million Dollars).....	8.23
Table 8-4:	Cost of Alternative 11 Supply from Off-Stream Reservoirs for West Irrigation District Zone A	8.25
Table 8-5:	Alternative Infrastructure Solutions for West Irrigation District Zone A	8.26
Table 9-1:	Cost of Alternative 9 - Supply from Lake Ontario via Zone A for West Irrigation District Zone B	9.5
Table 9-2:	Costs of Alternative 10 - Supply from Groundwater Wells for West Irrigation District Zone B	9.6
Table 9-3:	Cost of Alternative 11 - Supply from Off-Stream Reservoirs for West Irrigation District Zone B	9.7
Table 9-4:	Alternative Infrastructure Solutions for West Irrigation District Zone B	9.8
Table 10-1:	Costs of Regional Infrastructure Alternatives for East Irrigation District (Million Dollars except for Costs per Acre)	10.24
Table 11-1:	Cost of Alternative 3 - Supply from Welland Canal for South Irrigation District	11.6
Table 11-2:	Costs of Alternative 10 - Supply from Groundwater Wells for South Irrigation District	11.7
Table 11-3:	Cost of Alternative 11 Supply from Off-Stream Reservoirs for South Irrigation District	11.8
Table 11-4:	Alternative Infrastructure Solutions for South Irrigation District	11.9