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FEASIBILITY ASSESSMENT FOR THE HARVEST AND STORAGE OF STORMWATER FROM THE NOVA CANAL SYSTEM FOR USE AS A RECLAIMED WATER SUPPLEMENTAL SOURCE IN VOLUSIA COUNTY

Feasibility Assessment for the Harvest and Storage of Stormwater from the Nova Canal System for Use as a Reclaimed Water Supplemental Source in Volusia County

PREPARED FOR

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Executive Summary

This document reports on an investigation of the feasibility of diverting stormwater from the Nova Canal basin drainage system to supplement regional reclaimed water systems, or other non-potable uses. The Nova Canal drainage basin is located in east-central Volusia County and drains into the Halifax River. The study area is the 11th Street Canal, Reed Canal, and Halifax Canal basins, which all drain into Nova Canal and are located in the cities of Holly Hill, South Daytona, and Port Orange, respectively.

The average potential stormwater yields from the 11th Street, Reed, and Halifax canals are 3.4 mgd, 5 mgd, and 2.2 mgd, respectively; with a maximum yield of 4.5 mgd, 6.5 mgd, and 1.7 mgd, respectively. Of the 2.2 mgd yield from Halifax Canal, 1.2 mgd is already permitted for diversion through Bushman Pond. The storage requirements for these yields are 250 ac-ft, 400 ac-ft, and 250 ac-ft, respectively.

A review of the reclaimed water demands for utilities in the vicinity of Nova Canal reveals that only Port Orange is projecting a reclaimed water deficit. That deficit is approximately 2 mgd beginning in the year 2010. The cities of Holly Hill, Daytona Beach, and Ormond Beach all anticipate excess wastewater flows; with Daytona Beach having a projected excess of 10 mgd.

Conceptual Projects for Use of Stormwater to Supplement Reclaimed Water

Several potential projects are described within the Nova Canal drainage basin. Because this study's focus was the assessment of the timing and quantity of stormwater that could potentially available from the canal system construction, capital, and unit production costs are stated only for facilities needed to recover stormwater and pump to a storage or recharge facility. The unit production cost is based on the life of the project where the pumps are assumed to have a life of 26 years and pipes have a life of 40 years. A discount rate of 5.625% is assumed in estimating the life cycle cost of the project. These projects develop additional water supply while taking advantage of existing ponds, reservoirs, and recharge areas:

- 11th Street Canal – This project diverts a portion of stormwater discharges from the 11th Street Canal to Lake Hadley and then to a surface water storage facility located near the Rima Ridge Wellfield for augmenting reclaimed

water supplies. The recovered stormwater water will provide 3.4 mgd for irrigation uses. The unit production cost is estimated to be $0.96/Kgal of recovered storm water supply.

- Reed Canal –This project collects stormwater discharges from Reed Canal by way of the Reed Canal Stormwater Park. The stormwater is then transmitted to the Port Orange Water Reservoir and Recharge Basin to augment reclaimed water supplies. The recovered stormwater will provide 5.0 mgd for irrigation uses. The unit production cost is estimated to be $0.80/Kgal of recovered stormwater supply.
- Halifax Canal – This project collects additional stormwater discharges from the Halifax Canal in Bushman Pond. Stormwater from Bushman Pond is then transmitted to the Port Orange Reservoir and Recharge Basin. The recovered stormwater will provide 1.0 mgd for irrigation uses. The unit production cost is estimated to be $2.64/Kgal of recovered stormwater supply.

The cities of Holly Hill, South Daytona, and Port Orange could interconnect the proposed conceptual projects for stormwater reuse and realize possible cost savings.

Flood Control

Flooding problems have been documented in the Nova Canal basin. All of the proposed projects in this study include the installation of water control structures strategically located to hold back tidal flows and coastal storm surges into the canals. The cost of each structure is currently estimated at $1,500,000. Withdrawing stormwater from the canals for reclaimed water augmentation would also reduce flooding in the Nova Canal system. FEMA (2000) determined 100-year flood elevations between Nova Canal Road and Halifax River (Figure 1) to vary between 5 ft NGVD to 8 ft NGVD. Nova Canal reduces flood damage by collecting water from the surrounding drainage basin and discharging into the Halifax River. During the wet season, however, the banks of the Halifax River and Nova Canal can overflow when tides are higher than normal in the ocean and river because of offshore storms. For coastal storm surges that are less severe than a 100-year storm, and that do not overtop US 1, the control structures would stop the storm surge from entering the area lying between US 1 and Nova Canal Road. Flooding due to rainfall runoff would be reduced because water control structures would decrease tailwater elevations due to storm surges. Additional measures for flood reduction that will be required in combination with the water control structures include creating storage system inside or outside the Nova Canal basin and pumping water to the Halifax River. Because only a very small area within the Halifax River basin would be removed from tidal inundation after the installation of water control structures there would be no measurable change in the magnitude, frequency, and duration of flood events in the Halifax River system.

Water Quality Improvement

Due to extensive drainage improvements in the Nova Canal basin, the pollutant discharge loading has increased to the Halifax River. This has caused water quality and habitat degradation in the Halifax River estuary (FDEP 1997; Haydt and Frazel 2003). The project is expected to improve water quality of the Halifax River but a detailed modeling of historic, current, and post project conditions will be needed to quantify the impact of the project. The impact of the project on the water quality of Lake Hadley and the impact on fishing will need to be studied.

Halifax Canal Horizontal Well Demonstration Project

The Halifax Canal horizontal well demonstration project is located at the intersection of Dunlawton Avenue and Spruce Creek Road. A horizontal well recovery system is an alternative way for intake and filtration of surface water. The demonstration project will provide valuable information regarding potential well yield for stormwater recovery from the Halifax Canal. The project will also provide water quality information of the recovered water.

Future Work

This study is based on a planning level model which did not include a water quality component. Additional modeling work will be required to design structures and quantify water quality improvements. An operations plan or water control manual will need to be developed to support management of the system and projects described in this study. Also required will be personnel to operate the system. First steps in implementation of any selected project should be to install the water control structure and to identify potential storage areas.

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Abbreviations and Acronyms

ADF	Average Daily Flow
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FEMA	Federal Emergency Management Agency
O&M	Operation and Maintenance
PLRG	Pollutant Load Reduction Goals
SJRWMD	St. Johns River Water Management District
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WAV	Water Authority of Volusia County
WRF	Water Reclamation Facility
ac	acres
cfs	cubic feet per second
gpd	gallons per day
mgd	million gallons per day
Kgal	thousand gallons

Background and Introduction

Purpose

The investigation reported in this document was performed for the purpose of evaluating the feasibility of diverting stormwater from the Nova Canal basin drainage system to supplement regional reclaimed water systems. The stormwater, after treatment to reclaimed water standards, could be reused for nonpotable use in the cities of Daytona Beach, Ormond Beach, Holly Hill, South Daytona, and Port Orange in Volusia County. Common uses of reclaimed water include irrigating golf courses, road medians, residential landscapes, corporate grounds, agricultural fields, sports fields, and artificial recharge of shallow and deep aquifers. It could also be used for industrial heating and cooling, for car washes, and to replenish water levels in hydrologically altered wetlands.

The investigation addressed the currently projected nonpotable water demands and deficits in the planning area and the amount of reliable yield from the Nova Canal basin drainage system. It also identified the more cost effective methods of stormwater diversion and storage of the stormwater from the canals.

The Nova Canal basin drainage network consists of the 11th Street, Reed, and Halifax canals. The basin discharges into the Halifax River estuary. Increased freshwater flows from the Nova Canal system have degraded both the habitat conditions and water quality in the estuary (FDEP 1997; Haydt and Frazel 2003). Stormwater flow diversion from the canal system would reduce these impacts on the Halifax River estuary. Reducing stormwater flows is expected to significantly improve the health of the Halifax River estuary and help in meeting the total maximum daily load (TMDL) requirements of Florida Department of Environmental Protection (FDEP). Detailed modeling to quantify the impacts compared to historic, present, and future conditions will be required. In addition, local flooding within the Nova Canal watershed, particularly the lower areas along the 11th Street and Reed canals, could potentially benefit significantly in two ways. Placement of water control structures could prevent tide generated flooding and provide an enhanced ability to divert water away from the watershed prior to and during storm events. Additional measures for flood reduction in combination with the water control structures include creating storage systems inside or outside the Nova Canal basin and pumping water over to the Halifax River.

Benefits

Implementing the proposed water projects could have multiple water supply and environmental benefits including the following:

- Restoration of water quality in Halifax River
    - Reduce nutrient and pollutant loads to Halifax River to achieve potential pollutant load reduction goals (PLRG) and to achieve total maximum daily load (TMDL) reductions
    - Reduce harmful stormwater discharges to Halifax River estuary that disrupt the estuary's salinity regime
- Use as a source of reclaimed water augmentation
    - Provide alternative source for irrigation water supply
    - Provide augmentation water to large "reuse lakes" to the west of I-95
    - Provide artificial recharge of shallow and deep aquifers in areas such as the Port Orange Reclaimed Water Reservoir and Recharge Basin Project
- Conservation of groundwater
    - Use of stormwater instead of groundwater for nonpotable uses
- Flood Abatement
    - Provide storm surge protection
    - Increase stormwater storage volume
    - Provide pre-event drawdown capacity

Planning Area Description

The planning area in this study includes the basins of the 11th Street, Reed, and Halifax canals (Figure 1). These canal basins are in the cities of Holly Hill, South Daytona, and Port Orange, respectively. All three canal systems currently discharge to the Halifax River via a drainage network that short-circuits the historic meandering drainage pattern, thus significantly increasing the freshwater flows to the estuary. The predevelopment natural drainage pattern in these basins did not allow water to drain directly east due to the presence of the coastal ridge running parallel to the Halifax River.

Municipalities within the 11th Street planning area include the cities of Daytona Beach, Ormond Beach, and Holly Hill. Portions of the Nova Canal system that fall within the 11th Street planning area include the 11th Street Canal, Calle Grande Canal, Nova Road Canal North, Railroad Canal North, and Railroad Canal South. These canals discharge into the 11th Street Canal, which in turn discharges into the Halifax River through the 11th Street Canal outfall.

The city of Holly Hill is situated south of Ormond Beach and north of Daytona Beach near Florida's east coast. It is located on the mainland west of the Halifax River. The terrain is only slightly undulating. Holly Hill is on a ridge of hammock land, which is about 10 ft NGVD and which slopes downward toward the Halifax River. Canals and ditches all drain to the Halifax River or to the main LPGA Canal. There is a natural north–south ridge about one-fourth to one-half mile west of the Halifax River that was crossed by the 11th Street and Reed canals and now provides drainage from the Nova Canal basin to the Halifax River.

The city of South Daytona includes approximately 3.75 square miles bordering the Halifax River south of the city of Daytona Beach. The average elevation is 6.5 ft NGVD. Reed Canal flows east along Reed Canal Road, draining through the coastal ridge into the Halifax River. Further south of South Daytona along the Halifax River is the city of Port Orange. Nova Canal/Halifax Canal and Spruce Creek Basin are the major stormwater drainage systems for the coastal urban watershed of the city.

On March 20, 2007, Paul Haydt, SJRWMD, led the authors of this document (Zafar Hyder and William Dunn) on a site reconnaissance survey of the Nova Canal system. The major features and surface water management facilities in all three sub-basins were visited. Information gleaned from the survey was used in subsequent stages of the investigation. Photographs of the 11th Street, Reed Street, and Halifax Canal systems are provided in Appendices A, B, and C, respectively.

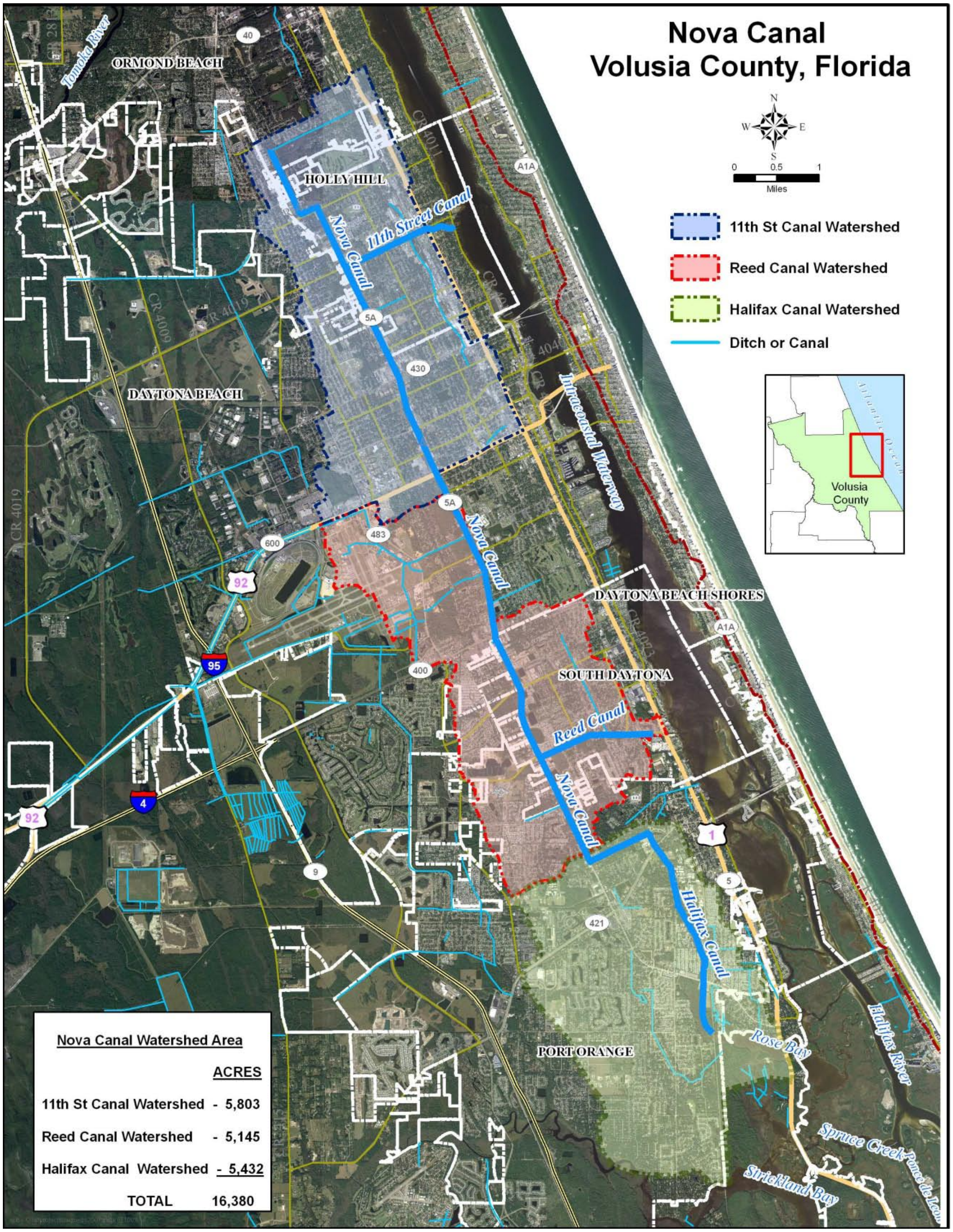

Figure 1. Location of Nova Canal System, Volusia County

Scope of Work

The study of the feasibility of diverting stormwater from the Nova Canal basin consisted of the following tasks:

1. Review current and future projections of nonpotable water demand
2. Estimate availability of stormwater from 11th Street, Reed, and Halifax canals
3. Develop storage/yield/reliability relationship for Nova Canal system
4. Review regulatory requirements related to surface water
5. Develop conceptual reclaimed water supply augmentation project(s) with the following characteristics
    - Phased implementation project design utilizing available storage and infrastructure for initial projects
    - Water flow control structures at canal discharges (Reed, 11th Street, and Halifax canals)
    - Capability to move surface water from canal system west to Port Orange Reclaimed Water Reservoir and Recharge Basin Project or into reuse distribution lines
    - Ability to convey large storm flows to the Halifax River during large storms
    - Capability to pre-pump the system to provide additional flood storage capacity
    - Conceptual schemes for diverting, storing, and distributing the storm water from the canals
    - Feasible interconnections to existing collection or distribution systems for water reclamation facilities (WRFs) in the area
6. Prepare planning level cost estimates for the project concepts

Demand and Source Analysis

Demand Analysis

The Water Authority of Volusia Master Water Plan (CDM 2006), also referred to as the WAV Plan, was reviewed. The plan provided projected reuse flows based on recovery from wastewater flows. The SJRWMD 2005 data base for existing use of reclaimed water by golf courses for the latest year of record was also reviewed. The following summary of reclaimed water use is based on the review of these water use summaries.

Existing Large Reclaimed Water Users

Existing large reclaimed water users in the area are:

- Riviera Golf Course and Country Club, Holly Hill – within 11th Street Canal drainage basin
- Daytona Beach Municipal Golf Course, Daytona Beach – outside the Reed Canal drainage basin, adjacent to north boundary of Reed Canal
- Pelican Bay Golf Course, Daytona Beach – one-half to one mile west of Reed Canal drainage basin

Potential Reclaimed Water Users in the Area

The WAV Plan identifies the following potential reclaimed water users in Holly Hill:

- Grove Street Park (6.9 acres), Holly Land Park (12.1 acres), Riviera Oaks Park (20.3 acres), Sunrise North Park (7.1 acres), The Club House Park (6.7 acres), Cypress Park, Holly Hill Elementary School, Holly Hill Middle School, Hurst Elementary School, and Bethune Cookman College

Potential reclaimed water users in South Daytona are:

- Atlantic High School, Big Tree Park, Reed Canal Park, and Rinker Materials

Potential reclaimed water users in Port Orange are:

- Creekside Middle School, Port Orange Elementary School, and Sugar Mill Elementary School

Reclaimed Water Demand Characteristics

Irrigation demands vary daily and seasonally. Most of the irrigation needs occur from April to October. The golf course (turf grass) irrigation demand ranges from 1,500 gallons per day/acre (gpd/ac) to 2,000 gpd/ac (USGS 2006). During drought periods the demand increases to 3,000 gpd/ac. SJRWMD collected irrigation water use data for several golf courses in Ormond Beach, Daytona Beach, and Port Orange. The golf courses are listed below.

- **Ormond Beach:** Plantation Bay Golf Club, Oceans Golf Club, Tomoka Oaks Country Club, River Bend Golf Links, LPGA International Champions Golf Club, LPGA International Legends Golf Club, and Halifax Plantation Golf Club
- **Daytona Beach:** Indigo Lakes Golf Club, Daytona Beach Golf Club, and Pelican Bay Country Club North
- **Port Orange:** Crane Lakes Golf Club and Spruce Creek Country Club

Summaries of irrigation water use by different source categories such as groundwater, surface water, and reclaimed water for Ormond Beach, Daytona Beach, and Port Orange for the above named golf courses for the year 2005 are given in Tables 1 through 3.

Table 1. Monthly irrigation use by source category for Ormond Beach golf courses*

Ormond Beach	Groundwater (mgd)	Surface Water (mgd)	Reuse (mgd)	All water (mgd)
Jan	0.548	0.397	5.269	6.214
Feb	0.677	0.603	12.476	13.757
Mar	0.562	0.389	5.730	6.681
Apr	0.754	1.197	25.443	27.394
May	0.713	1.008	17.796	19.517
Jun	0.520	0.445	8.149	9.115
Jul	0.676	0.784	5.989	7.449
Aug	0.613	1.148	5.883	7.644
Sep	0.589	0.843	5.549	6.981
Oct	0.490	0.600	2.324	3.413
Nov	0.521	0.812	14.241	15.575
Dec	0.461	0.436	2.690	3.587
Total	**7.125**	**8.662**	**111.540**	**127.326**
ADF	**0.594**	**0.722**	**9.295**	**10.611**

*** Water reuse data provided by SJRWMD for the year 2005**

Table 2. Monthly irrigation use by source categories for Daytona Beach golf courses*

Daytona Beach	Groundwater (mgd)	Surface Water (mgd)	Reuse (mgd)	All water (mgd)
Jan	0.000	0.092	5.379	5.471
Feb	0.000	0.121	26.622	26.743
Mar	0.000	0.070	4.008	4.078
Apr	0.000	0.179	32.924	33.103
May	0.000	0.130	17.867	17.997
Jun	0.000	0.205	2.922	3.127
Jul	0.000	0.171	17.958	18.129
Aug	0.000	0.097	20.615	20.712
Sep	0.000	0.119	9.830	9.949
Oct	0.000	0.070	6.967	7.037
Nov	0.000	0.113	31.488	31.601
Dec	0.000	0.064	6.088	6.152
Total	**0.000**	**1.430**	**182.668**	**184.098**
ADF	**0.000**	**0.119**	**15.222**	**15.342**

*** Water reuse data provided by SJRWMD for the year 2005**

Table 3. Monthly irrigation use by source categories for Port Orange golf courses*

Port Orange	Groundwater (mgd)	Surface Water (mgd)	Reuse (mgd)	All water (mgd)
Jan	0.000	0.000	0.092	0.093
Feb	0.000	0.000	0.075	0.075
Mar	0.000	0.000	0.138	0.138
Apr	0.000	0.000	0.111	0.111
May	0.000	0.000	0.204	0.204
Jun	0.000	0.000	0.260	0.260
Jul	0.000	0.002	0.111	0.112
Aug	0.000	0.002	0.249	0.251
Sep	0.000	0.002	0.158	0.160
Oct	0.000	0.002	0.172	0.174
Nov	0.000	0.005	0.142	0.147
Dec	0.000	0.003	0.141	0.144
Total	**0.003**	**0.015**	**1.853**	**1.871**
ADF	**0.000**	**0.001**	**0.154**	**0.156**

*** Water reuse data provided by SJRWMD for the year 2005**

The information provided in the tables 1 through 3 show characteristics of irrigation water uses over a period of one year. The water use reported in the "all water" columns of these figures is also plotted in Figure 2. The water uses are higher during the months with less rainfall and lower during the months with higher rainfall. This results in higher supply of stormwater when the demand is lower requiring storage area for the excess water. The significance of this figure is in translation of annual average demands to monthly demands.

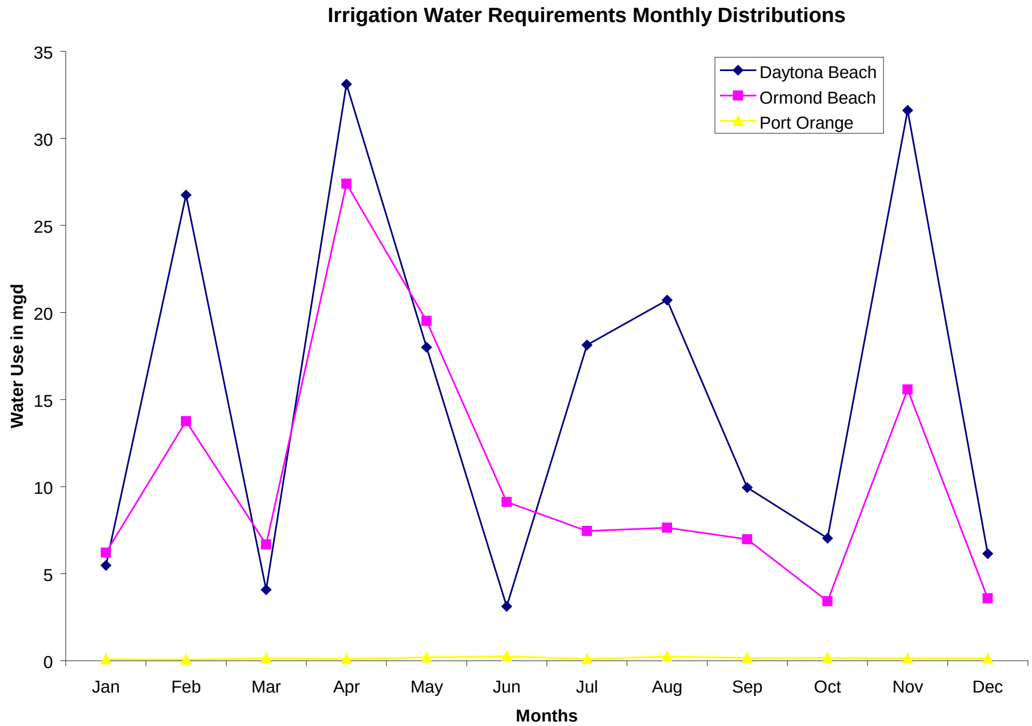

Figure 2. Actual golf course irrigation water use by month for the year 2005

Projected Reclaimed Water Usage

The WAV Plan projects reclaimed water usage for the cities of Daytona, Holly Hill, Ormond Beach, and Port Orange (Table 4). The city of South Daytona maintains its water distribution and wastewater collection systems but purchases its water from and transfers its sewage to the city of Daytona Beach. Port Orange is the only city for which the WAV Plan projects a deficit for reclaimed water supply. The amount needed is approximately 2 mgd beginning in the year 2010. All the cities listed in Table 4 are projected to have excess wastewater flow with Daytona Beach having a significant excess of 10 mgd.

Table 4. Projected reclaimed water usage

City		2010 (mgd)	2015 (mgd)	2020 (mgd)	2025 (mgd)
Daytona Beach	Plant Capacity	20.0	23.0	23.0	23.0
	Wastewater Flow	15.79	17.50	17.50	17.50
	Reuse Flow	5.53	6.13	6.13	6.13
	Excess (Deficit)	10.26	11.37	11.37	11.37
Holly Hill	Plant Capacity	3.0	3.6	3.6	3.6
	Wastewater Flow	2.38	2.58	2.77	2.87
	Reuse Flow	0.60	1.29	1.66	1.72
	Excess (Deficit)	0.78	1.29	1.11	1.15
Ormond Beach	Plant Capacity	6.0	6.0	6.0	6.0
	Wastewater Flow	4.89	5.26	5.68	5.76
	Reuse Flow	3.02	3.51	4.08	4.12
	Excess (Deficit)	1.87	1.75	1.60	1.64
Port Orange	Plant Capacity	12.0	12.0	12.0	12.0
	Reuse Flow	6.90	7.20	7.20	7.20
	Excess (Deficit)	(2.0)	(2.10)	(2.20)	(2.30)

Stormwater Supply Source Analysis

The Nova Canal watershed area includes the 11th Street, Reed, and Halifax canals. Nova Canal runs north and south and becomes Halifax Canal before draining into Halifax River; the 11th Street Canal and Reed Canal drain east to Halifax River. USGS gage data is available for the 11th Street, Reed, and Halifax canals. The mean daily flows of the three canals are shown in Table 5.

Table 5. Mean daily flow for the three canals

Canal	Mean Flow (cfs)
11th Street	12.0
Reed	17.0
Halifax	12.0

Daily rainfall data from a rainfall station near Holly Hill was available from the SJRWMD database (SJRWMD 2007). The rainfall amounts for the years 2000 to 2005 were close to the average annual rainfall of 54 in. for the area. The period of record low rainfall at this station occurred in 2006 when annual recorded rainfall was 29 in. Figure 3 shows the flow duration curves for the 11th Street, Reed, and Halifax canals.

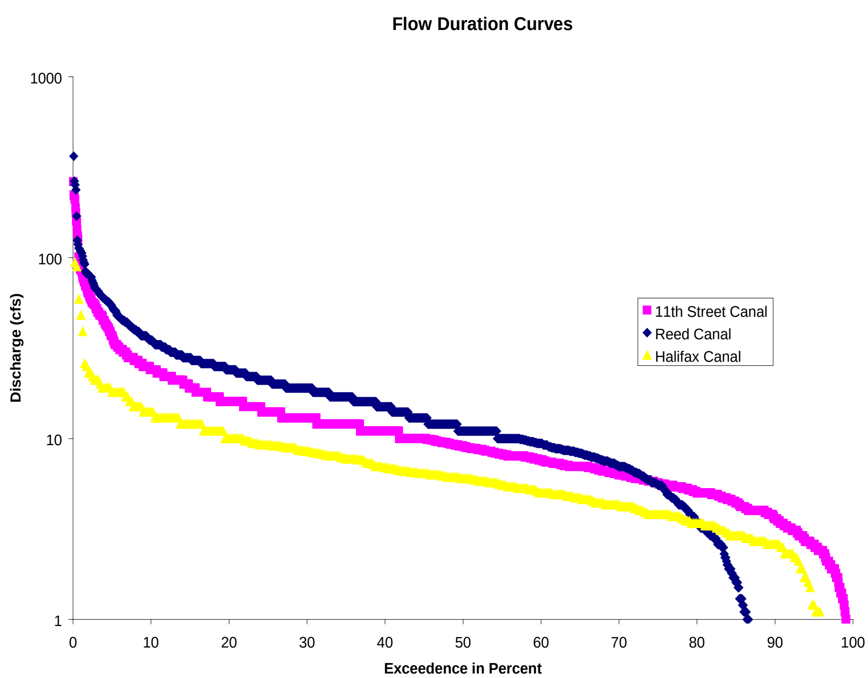

Figure 3. Flow duration curves for 11th Street, Reed, and Halifax canals

Yield Estimates

Nova Canal could be used as a supplemental source to augment reclaimed water supplies. In most reclaimed water systems the availability of reclaimed water and demand for the water do not match on a daily basis. Therefore, storage facilities are typically needed to manage the supply to best meet demands. When supply exceeds demand water can be diverted and stored, and when demands exceed supplies the water can be withdrawn from storage.

Methodology

A spreadsheet-based water budget model was developed. The model calculates a water balance based on inflows and outflows. The components of the water balance include direct rainfall on the reservoir, runoff from the watershed into the canals as inflow, evaporation from the pond surface, seepage from pond bottom, and outflow. Two types of outflow are considered, one is surface water pumped out of the pond for use, and the other is the weir discharges when the volume of water exceeds the available storage capacity of the pond. The water budget can be represented by a general formula (equation 1) where the change in storage is equal to the difference of the sum of inflows and the sum of outflows.

$$\Delta Storage = \sum Inflows - \sum Outflows \qquad \text{(1)}$$

Equation 2 shows the parameters of the water budget model.

$$S_t = S_{t-1} + (R + P_i - E - P_w - P_p - G) \qquad \text{(2)}$$

Where, S_t = Surface water storage at time t, ac-ft

S_{t-1}= Surface water storage at time t-1, ac-ft

R = Rainfall, ac-ft/day

$P_{i/w/p}$= Point Inflows and outflows through culverts/weir/pumps, ac-ft/day

E = Evaporation, ac-ft/day

G = Seepage that enters groundwater, ac-ft/day

Model Parameters

Evaporation

Evaporation (E) is water loss through evaporation. Lake evaporation rates are needed by the water budget model to estimate daily evaporation losses from the reservoir. It is computed by lake pan evaporation rates, E, and a lake pan evaporation coefficient, K (equation 3). Evaporation rates used in this simulation are shown in table 6.

$$E = K_{pan} * E_{pan} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Table 6. Estimated monthly evaporation

Month	E (in)	Month	E (in)
Jan	2.09	July	4.88
Feb	2.60	August	4.80
Mar	3.58	Sep	4.02
Apr	4.49	Oct	3.59
May	5.31	Nov	2.72
June	4.41	Dec	2.09

Seepage

The seepage or percolation losses resulting from the vertical movement of ponded water into the saturated soil is estimated using equation 4.

$$Q = K_v A \frac{dh}{dv} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where, K_v = Vertical Hydraulic Conductivity, ft/day

A= Surface area of ponded water, acres

dh = Depth of ponded water, ft

dv= Thickness of soil layer between pond and groundwater, ft

The only parameter in the water budget that may show significant uncertainty is the seepage as the hydraulic conductivity of the soil layer between the pond bottom and the groundwater has to be investigated in the field. Also, surface water and groundwater interaction is ignored in this simulation.

Storage

Identification of storage areas is critical to the success of the project and an important consideration for the local governments. One potential storage area is the canals themselves along with any bank storage that would occur. Storing water in the canals will require active management of the canal water levels. Changing use of the canal to a reservoir will require evaluation of loss of level of service or flood risk. There are several structural methods to change the canal to a reservoir. Comparisons of these structural measures will be required. A preliminary estimate of storage in the 11th Street, Reed, and Halifax canals shows that there is a limited storage capacity of 5 ac-ft in each of these canals. This storage capacity in the canals is too small for any economically feasible water reuse purposes. Storage reservoirs are needed for the reliable availability of water.

Constraints on Withdrawal

There are three constraints on diversion of stormwater from the canals. The first constraint is that there may not be enough storage area to store all runoff from a large storm event. Secondly, all the water from the canals cannot be withdrawn, as such action would create a breeding ground for mosquitoes. Also, in the absence of a control structure, withdrawal of all water will result in higher intrusion of saltwater in the canals.

Yield Analysis

Two rainfall conditions were considered: 1. average rainfall (54 in.) and 2. drought period (29 in.). For each rainfall condition two scenarios were evaluated:

1. All flows through the canals can be diverted into a storage reservoir until the reservoir is full. This is the maximum yield from the three sources. The Overflow/Bypass row in the Tables 7 through 14 shows the quantity of water that cannot be captured when the reservoir is full.

2. Diverting all flows from the canals may cause increased intrusion of tidal flows upstream of the canals and an increase in mosquito breeding habitat. Hence flows are diverted to storage when the

flows in the canals are above the 66% exceedance levels (Figure 3). Where exceedance level is defined as the percentage of time a given discharge is equaled or exceeded. This alternative yield is called the average yield from the three sources.

The water pumped from the reservoir for irrigation is defined as yield. The estimated yield for 70% reliability is shown in Tables 7 through 14, where reliability is measured as the percent of time the storage provides the defined yield.

Table 7. Annual water budget for 11th Street Canal – average rainfall, all flows are diverted

INFLOW			OUTFLOW		
Parameter	Ac-ft	%	Parameter	Ac-ft	%
Starting Storage	100	1	Ending Storage	109	1
Direct Rain	233	2	Evaporation	202	2
Runoff/Inflow	9737	97	Seepage	160	2
			Overflow/Bypass	2968	29
			Yield	6642	66
Totals	**10070**	**100**	**Totals**	**10081**	**100**

Table 8. Annual water budget for 11th Street Canal – average rainfall, two-thirds of flows are diverted

INFLOW			OUTFLOW		
	Ac-ft	%		Ac-ft	%
Starting Storage	100	1	Ending Storage	90	1
Direct Rain	233	3	Evaporation	165	2
Runoff/Inflow	6954	95	Seepage	152	2
			Overflow/Bypass	3069	42
			Yield	3812	52
Totals	**7287**	**99**	**Totals**	**7288**	**99**

Table 9. Annual water budget for Reed Canal – average rainfall, all flows are diverted

INFLOW			OUTFLOW		
	Ac-ft	%		Ac-ft	%
Starting Storage	200	2	Ending Storage	109	1
Direct Rain	384	3	Evaporation	302	2
Runoff/Inflow	12433	96	Seepage	252	2
			Overflow/Bypass	4089	32
			Yield	8223	63
Totals	**13017**	**100**	**Totals**	**12975**	**100**

Table 10. Annual water budget for Reed Canal – average rainfall, two-thirds of flows are diverted

INFLOW			OUTFLOW		
	Ac-ft	%		Ac-ft	%
Starting Storage	200	2	Ending Storage	163	2
Direct Rain	384	3	Evaporation	277	3
Runoff/Inflow	9788	94	Seepage	244	2
			Overflow/Bypass	4069	39
			Yield	5615	54
Totals	**10372**	**100**	**Totals**	**10368**	**100**

Table 11. Annual water budget for Halifax Canal – average rainfall, all flows are diverted

INFLOW			OUTFLOW		
	Ac-ft	%		Ac-ft	%
Starting Storage	125	2	Ending Storage	172	3
Direct Rain	232	4	Evaporation	200	3
Runoff/Inflow	5576	94	Seepage	153	3
			Overflow/Bypass	1184	20
			Yield	4528	71
Totals	**5933**	**100**	**Totals**	**5967**	**100**

Table 12. Annual water budget for Halifax Canal – average rainfall, two-thirds of flows are diverted

INFLOW			OUTFLOW		
	Ac-ft	%		Ac-ft	%
Starting Storage	125	3	Ending Storage	160	4
Direct Rain	232	6	Evaporation	170	4
Runoff/Inflow	3801	91	Seepage	149	4
			Overflow/Bypass	1217	29
			Yield	2483	59
Totals	**4158**	**100**	**Totals**	**4179**	**100**

Table 13. 11th Street Canal drought period-all flows are diverted

INFLOW			OUTFLOW		
	Ac-ft	%		Ac-ft	%
Starting Storage	100	3	Ending Storage	82	2
Direct Rain	122	3	Evaporation	183	5
Runoff/Inflow	3505	94	Seepage	117	3
			Overflow/Bypass	450	12
			Yield	2911	78
Totals	**3727**	**100**	**Totals**	**3743**	**100**

Table 14. 11th Street Canal drought period, two-thirds flow are diverted

INFLOW			OUTFLOW		
	Ac-ft	%		Ac-ft	%
Starting Storage	100	7	Ending Storage	55	3
Direct Rain	122	7	Evaporation	145	9
Runoff/Inflow	1454	87	Seepage	106	6
			Overflow/Bypass	350	21
			Yield	1029	61
Totals	**1676**	**100**	**Totals**	**1685**	**100**

Summary Results of Potential Yield

Tables 15 through 17 summarize the results in the previous section. In reviewing the available yield it should be noted that a typical 75-acre golf course will require 2000 gpd/ac of water, which is equivalent to 0.23 cfs. On average, the yield from the 11th Street, Reed, and Halifax canals are 7 cfs, 10 cfs, and 4.5 cfs, respectively. The storage requirements for these yields are 250 ac-ft, 400 ac-ft, and 250 ac-ft, respectively. Reed and Halifax canals drought period analysis cannot be performed because of a lack of data but an estimate was made in the summary data table assuming similar characteristics as those used for the 11th Street Canal analysis.

Table 15. Summary of yield and storage requirements – 11th Street Canal

Rainfall	Diversion Condition	Storage (ac-ft)	Maximum Yield (cfs)	Average Yield (cfs)
Average	All	250	11	9.2
Average	Top 67%	250	7	5.3
Drought	All	250	5.25	4.0
Drought	Top 67%	250	2	1.4

Table 16. Summary of yield and storage requirements – Reed Canal

Rainfall	Diversion Condition	Storage (ac-ft)	Maximum Yield (cfs)	Average Yield (cfs)
Average	All	400	14	11.4
Average	Top 67%	400	10	7.8
Drought	All	400	6.7	5.0
Drought	Top 67%	400	2.6	2.0

Table 17. Summary of yield and storage requirements – Halifax Canal

Rainfall	Diversion Condition	Storage (ac-ft)	Maximum Yield (cfs)	Average Yield (cfs)
Average	All	250	7	6.3
Average	Top 67%	250	4.5	3.4
Drought	All	250	3.3	2.7
Drought	Top 67%	250	1.3	0.9

Development and Evaluation of Conceptual Projects

Several attributes are recommended to be incorporated into the conceptual reuse supply projects. The attributes include the following:

- Structures on 11th Street, Reed, and Halifax canals are required to stop tidal flows into the canals from the Halifax River and to create enough head in the canals for canal intake structures. This measure will reduce tidal inflows to inland areas and thereby reduce flooding. The tailwater conditions will be managed to reduce chances of flooding. Installing water control structures will not cause or contribute to any increase in the magnitude, frequency, or duration of coastal flooding in the Halifax River estuary.
- Maintain ability for canals to convey large storm discharge during extreme high water, storm, and emergency events.
- Size facilities to assure that there is adequate capacity in both receiving system and delivery network.
- Provide capability to pre-pump system to provide additional storm storage capacity.
- Cost savings may be possible with raw and treated water interconnectivity from the three canal sources. An interconnected system may provide flexibility and efficiency in water management, maximize usage, and increase reliability at a cheaper cost. Some interconnections may require a regional facility and cooperation among utilities.
- Consider using a phased approach utilizing smaller regional facilities as an effective option to successfully build a cooperative network in the region. Because of the expense of storage and delivery infrastructure requirements and local perceptions of needs and benefits, levels of local acceptance of, endorsement of, and participation in the plan may vary.
- Regulatory requirements for the use of surface water and stormwater as a supplement to reclaimed water are provided in 62-610*, Florida Administrative Code*, (*F.A.C.*). According to the code, surface water and stormwater may be used to supplement a reclaimed water supply if sufficient treatment and disinfection is provided such that the fecal coliform and

total suspended solids limits established for high-level disinfection in subsection 62-600.440(5), F.A.C., are met for the source before mixing with the reclaimed water.

Table 18 shows existing related projects and Table 19 shows planned or ongoing related projects.

Table 18. Related projects existing in the planning area

Existing Stormwater and Reclaimed Water System Features	
Project	**Description**
1) Bushman Stormwater Park	A 23-acre site known as Bushman Stormwater Park, city of Port Orange water reuse augmentation project. Four ponds capture stormwater runoff and reroute it to a treatment plant so that it can be used as reuse water. The project is permitted for up to 1.2 mgd, depending on water levels and rainfall conditions.
2) City of Port Orange - WRF	The city of Port Orange 12 mgd capacity R.D. Huffman Reclaimed water plant is between Bushman Park and Halifax Canal demonstration project.
3) City of South Daytona, Rinker Ponds	Towards the end of Reed Canal where it discharges into the Intracoastal, there are several ponds south of the canal. The ponds are owned by Rinker Materials Corporation. The ponds can be used to retain stormwater flowing through Reed Canal.
4) City of South Daytona, Stevens Canal Project	A 2.6-acre tract that fronts on Big Tree Road between U.S. 1 and Nova Road in South Daytona helps attenuation of the stormwater flow in Stevens Canal, with the use of a wet detention. Stevens Canal drains into Reed Canal.
5) Daytona Beach Bethune Point WRF	City of Daytona Beach owns and operates the 10 mgd capacity Bethune Point Wastewater Treatment Plant. The plant provides reclaimed water to the downtown areas and eastern portion of Daytona Beach.
6) City of Daytona Beach Westside Regional WRF	The city of Daytona Beach Westside Regional WRF has a permitted capacity of 10 mgd and supplies reclaimed water to the LPGA golf course and other reuse customers in the western part of Daytona Beach. Bethune Point and Westside reclaimed water distribution systems have limited interconnections.
7) Daytona Beach Bellevue Park, B5 and B6 Stormwater ponds	This 20-acre pond provides treatment for stormwater. The goals of the project are to improve the quality of stormwater runoff discharged to the Halifax River and to alleviate localized flooding associated with extreme storm events. The pond water can discharge directly to Halifax River but is pumped into the Nova Canal.
8) City of Holly Hill Centennial Park	City of Holly Hill Centennial Park and Lake Hadley is bordered on the east by FEC Railway tracks, the south by 10th Street (a thoroughfare to SR5-Nova Road) and the west and north by the Public Works Complex. US 1 is one block east of the Park.
9) Holly Hill WRF	The city of Holly Hill WRF is located next to Centennial Park. Holly Hill WRF has a capacity of 2.4 mgd.

Table 19. Related water projects planned and proposed in the planning area

Planned and Proposed Stormwater and Reclaimed Water System Projects	
Project	**Description**
1) Holly Hill and Ormond Beach Reclaimed Water System Expansion	The interconnect would be made through the extension of a 12-inch transmission main to the existing Ormond Beach 8-inch main located in the Nova Road right-of-way. Holly Hill could divert up to 750,000 gallons per day into the Ormond Beach system.
2) Holly Hill WRF	The Holly Hill WRF capacity is being upgraded to 3.6 mgd from 2.4 mgd.
3) City of South Daytona, Stormwater Park	An 11-acre site has been acquired by the city of South Daytona to be transformed into a stormwater park. Stevens Canal and Reed Canal flows will be diverted through the stormwater facility for water quality improvement before the treated water is discharged back into the Reed Canal.
4) Daytona Beach Reclaimed Water Transmission Project	A 24-inch reuse transmission main interconnect from the Bethune Point WWTP to the Westside Regional Reuse Service Area is proposed to convey excess reuse flows from the Bethune Point WWTP to the Westside Regional WWTP.
5) South Daytona Reclaimed Water System Expansion Project	The city of South Daytona is planning to construct at 10-inch diameter reclaimed water main along US 1 (Ridgewood Avenue) from the northern city limits to the southern city limits. Total length is approximately 13,200 linear feet.
6) Port Orange Reclaimed Water Transmission Main Project	The proposed project will be constructed along the South Williamson Boulevard right-of-way. This project will allow Port Orange to fully utilize an additional 365 million gallons of reclaimed water per year.
7) Port Orange Pioneer Trail Storage and Pumping Facility Project	The city of Port Orange has established the Pioneer Trail area as the site for additional reclaimed water storage and pumping facilities. The location is near the service area boundary with New Smyrna Beach and is well suited to a reclaimed water interconnect.
8) Port Orange Reclaimed Water Reservoir and Recharge Basin Project	This project includes a 3.0 million gallon storage tank, two reservoir/recharge basins, 8,500 linear feet of horizontal recovery wells, recovery pumps/controls, and high-service distribution pumps. The project also includes the harvest of storm water to transfer and store in the basins as further reclaimed water supply augmentation and recharge.
9) Rima Ridge Reservoir and Recharge Basin Project	This is a conceptual project idea that does not have a sponsor. It would include reservoir/recharge basins perhaps located in the Rima Ridge area in northeast Volusia County; and west of the Ormond Beach and Holly Hill wellfields.

Conceptual Projects for Use of Stormwater to Supplement Reclaimed Water

Because this study's focus was the assessment of the timing and quantity of stormwater that could potentially available from the canal system the conceptual projects described in the Nova Canal basin are partial projects only. The facilities included in the cost estimates are:

- The water control structures for holding back stormwater flows in the canals from discharge into the Halifax River
- Pumping and transmission for delivering the water to storage facilities

The project cost estimates do not include:

- The construction of new storage/recharge basins; or modifications to existing storage/recharge basins
- The treatment of the stormwater to reclaimed water standards or the construction, operation and maintenance of the reuse distribution systems

These planning level costs are developed for the conceptual projects based on 2007 cost estimates. Capital as well as operation and maintenance (O&M) costs are estimated for each project's included component facilities. O&M costs for the transmission systems and water control structures are not included because they are relatively small when compared to the range of uncertainty in the equivalent annual cost. In addition, annualized total unit production cost ($/1000 gallons) are included. The unit production cost is based on the life of the project where the pumps are assumed to have a life of 26 years and pipes have a life of 40 years. A discount rate of 5.625% is assumed in estimating life cycle cost of the project.

All projects have a direct water supply benefit in terms of providing a supplemental source of reclaimed water, but each also provides other benefits, that include:

- Recovered stormwater can also be used for aquifer recharge
- Flood avoidance resulting in reduced flood damage costs, particularly in Holly Hill and South Daytona
- Environmental benefit from treating and diverting harmful stormwater discharges to the Halifax River estuary

Because only a relatively small area would be removed from tidal inundation after the installation of water control structures there would be no measureable change in the magnitude, frequency, and duration of flood events in the Halifax River system. A 5- to 10-acre area of the canal system is expected to be removed from tidal inundation. By comparison the main body of the Halifax River lagoon occupies approximately 10,000 acres in the reach from the Volusia-Flagler county line south to Ponce Inlet (Scholl et al. 1980). Thus, the area that would be removed from tidal flux is only 0.1% of the main body of the lagoon.

This report utilizes the costing protocols in SJRWMD's report on cost estimates of Water Supply and Reuse System Component Costs (*Engineering assistance in updating information on water supply and reuse system component cost*, SJ2008-SP10). Based on the review and analysis in the preceding sections of this document, a conceptual supply project within each of the three sub-basins of the Nova Canal system is presented below.

The water recovered from the three canals when moved to storage areas would be considered surface water by FDEP and regulated as such.

11th Street Canal Project

Project costs shown in Table 20 include the installation of a water control structure either at the Daytona Avenue Bridge or near the Centennial Park on 11th Street Canal. They also include pumping stations and a transmission system to divert 3.4 mgd of stormwater from the 11th Street Canal through Lake Hadley in Centennial Park to a proposed reservoir/recharge facility located in the Rima Ridge area in northeast Volusia County (see Table 19 – project number 9). Approximately 250 ac-ft of storage area is needed. The cost of a reservoir/recharge/storage facility is not included in the cost estimate. Treatment costs that may be needed are not included in the cost estimate. The conceptual project for reuse of water from the 11th Street Canal is depicted in Figure 4. The costs of the surface water pumping system and piping are given in Table 20.

Table 20. Cost estimate for 11th Street Canal project

Major Component	Construction Cost	Capital Cost	O&M Cost ($/yr)	Equivalent Annual Cost ($/yr)	Unit Production cost $/Kgal.
Pumping Stations	$3,830,000	$4,787,500	$95,000	$449,817	$0.36
Transmission system	$8,096,624	$10,120,780		$641,118	$0.52
Water Control Structure	$1,500,000			$95,025	$0.08
TOTALS	**$13,426,624**	**$14,908,280**	**$95,000**	**$1,185,960**	**0.96**

Reed Canal Project

Project costs shown in Table 21 include the installation of a water control structure; pump stations; and a transmission system to convey stormwater to the Port Orange Reclaimed Water Reservoir and Recharge Basin Project. The stormwater will be routed through the existing Reed Canal Stormwater Park for short-term storage and water quality treatment before being pumped to the Port Orange Reclaimed Water Reservoir and Storage Basin. The conceptual project for the storage of water from the Reed Canal is depicted in Figure 5. The cost estimate for the Reed Canal project is shown in Table 21. The cost of a reservoir/recharge/storage facility is not included in the cost estimate. Treatment costs that may be needed are not included in the cost estimate.

Table 21. Cost estimate of Reed Canal project

Major Component	Construction Cost	Capital Cost	O&M Cost ($/yr)	Equivalent Annual Cost ($/yr)	Unit Production cost $/Kgal.
Pumping Stations	$3,830,000	$4,787,500	$95,000	$449,817	$0.25
Transmission System	$10,795,499	$13,494,373		$854,824	$0.47
Water Control Structure	$1,500,000			$95,025	$0.08
TOTALS	**$16,125,499**	**$18,281,873**	**$95,000**	**$1,399,666**	**$0.80**

Halifax Canal Project

Project costs shown in Table 22 include the installation of a water control structure; pumping stations; and a transmission system to the Port Orange Reclaimed Water Reservoir and Recharge Basin Project. Currently, 1.2 mgd of the Halifax Canal flow is permitted for diversion through Bushman Pond leaving an extra 1 mgd of flow. The extra 1 mgd of stormwater flow can be withdrawn and transferred to the Port Orange Reclaimed Water Reservoir and Storage Basin. A conceptual project for reuse of water from the Halifax Canal is depicted in Figure 6. Although the cost of a surface water pumping system and piping are included in the project costs, it is possible that an upgrade to the capacity of the existing system will be much cheaper than a new system. An upgrade of the existing system may result in a lower unit production cost than the estimated value of $2.64 /K gallon of surface water as shown on Table 22. The cost of a reservoir/recharge/storage facility is not included in the cost estimate. Treatment costs that may be needed are not included in the cost estimate.

Table 22. Cost estimate of Halifax Canal project

Major Component	Construction Cost	Capital Cost	O&M Cost ($/yr)	Equivalent Annual Cost ($/yr)	Unit Production cost $/Kgal.
Pumping Stations	$3,110,000	$3,887,500	$78,000	$366,115	$1.00
Transmission System	$7,176,542	$8,970,677		$568,263	$1.56
Water Control Structure	$1,500,000			$95,025	$0.08
TOTALS	**$11,786,542**	**$12,858,177**	**$78,000**	**$1,029,403**	**$2.64**

Halifax Canal Horizontal Well Demonstration Project

The results of Halifax Canal horizontal well demonstration project might provide information on alternative ways of getting stormwater that will require less treatment. The city of Port Orange Halifax Canal horizontal well demonstration project is located at the intersection of Dunlawton Avenue and Spruce Creek Road. A horizontal well was installed in a dry pond near the Halifax Canal. A horizontal well recovery system is an alternative way for intake and filtration of surface water. The demonstration project will provide valuable information regarding potential well yield and water quality for stormwater recovery from the Halifax Canal. Potentially the recovered surface water will not require any filtration or disinfection treatment.

Figure 4. Conceptual pipeline for diversion of stormwater from 11th Street Canal system

Figure 5. Conceptual pipeline for diversion of stormwater from Reed Street Canal system

Figure 6. Conceptual pipeline for diversion of stormwater from Halifax Canal system

Project Implementation Plan

A breakdown of a proposed schedule including major milestones is shown in Table 23.

Table 23. Project Schedule

Major Component	Estimated time needed from start of project study
Feasibility Study	6 months
Real Estate Acquisition	1 year
Hydrologic and Hydraulics Modeling	1 year
Value Engineering and Basis of Design Report	1 year
Plans and Specifications	1 year
Construction completed	4.5 years from start of project study

Value engineering in the above schedule will evaluate different design improvements that may reduce project costs. Design improvements may include reversing flows and using the existing Nova Canal system to channel the flows toward storage areas away from the Halifax River. This will reduce the cost of pipes needed to take water to the storage areas. The basis of design report includes the recommendation of value engineering and provides the technical basis for the project's plans and specifications.

Summary and Conclusion

The average yields from the 11th Street, Reed, and Halifax canals are 3.4 mgd, 5 mgd, and 1.0 mgd, respectively, with a maximum yield of 4.5 mgd, 6.5 mgd, and 2.9 mgd, respectively, for about 70 percent of the time. The storage requirements for these yields are 250 ac-ft, 400 ac-ft, and 250 ac-ft, respectively.

The proposed measures to reuse stormwater can be implemented separately if desired. The rest of the water would continue to drain into the Halifax River. Stormwater diversion also removes some amount of the nutrient load, thus the proposed measures should also improve water quality before the residual stormwater runoff flows into the Halifax River.

Conceptual Projects for Use of Stormwater to Supplement Reclaimed Water

The following projects have been identified as part of this feasibility investigation. Each of these projects would take advantage of existing ponds, reservoirs and recharge areas:

- 11th Street Canal – This project diverts a portion of stormwater discharges from the 11th Street Canal to Lake Hadley and then to a western reclaimed water storage facility located near the Rima Ridge Wellfield. The reclaimed water would provide 3.4 mgd for irrigation, or other non-potable uses. The unit production cost is estimated to be $0.96/Kgal of surface water supply.
- Reed Canal –This project collects stormwater discharges from Reed Canal by way of the Reed Canal Stormwater Park. The stormwater is then transmitted to Port Orange Water Reservoir and Storage Basin. The stormwater would provide 5 mgd for irrigation, or other non-potable uses. The unit production cost is estimated to be $0.80/Kgal rate of surface water supply.
- Halifax Canal – This project collects additional stormwater discharges from the Halifax Canal by collecting flows at Bushman Pond and then eventually pumping that water to the Port Orange Water Reservoir and Storage Basin. The surface water would provide 1.0 mgd for irrigation, or other non-potable uses. The unit production cost is estimated to be $2.64/Kgal of surface water supply.

The cities of Holly Hill, South Daytona, and Port Orange could possibly realize significant cost savings from integrating any proposed projects for stormwater reuse via their reclaimed water systems. Geographically, the cities of South Daytona and Port Orange are closer to each other, whereas Ormond Beach is closer to Holly Hill. The cities of Ormond Beach and Holly Hill have an ongoing project to connect the reclaimed water distribution system of the two cities. The cities of South Daytona and Port Orange are also considering interconnecting their reclaimed water systems.

Flood Control

Flooding problems have been documented in the Nova Canal basin. All of the proposed projects in this study include the installation of water control structures strategically located to hold back tidal flows and coastal storm surges into the canals. The cost of each control structure is currently estimated at $1,500,000. Withdrawing stormwater from the canals for reclaimed water augmentation will also reduce flooding in the Nova Canal system. FEMA (2000) determined 100-year flood elevations between Nova Canal Road and Halifax River (Figure 1) to vary between 5 ft NGVD to 8 ft NGVD. Nova Canal reduces flood damage by collecting water from the surrounding drainage basin and discharging into the Halifax River. But during the wet season, the banks of Halifax River and Nova Canal can overflow when tides are higher than normal in the oceans and rivers from offshore storms. For coastal storm surges that are less severe than a 100-year storm, and that do not overtop US 1 the control structures would stop the storm surge from entering the area lying between US 1 and Nova Canal Road. Flooding due to rainfall runoff would be reduced because the control structures would decrease tailwater elevations due to storm surges. Additional reductions in flooding could only be achieved by other measures such as creating storage and pumping water over to the Halifax River. Because only a very small area within the Halifax River basin would be removed from tidal inundation after the installation of water control structures there would be no measureable change in the magnitude, frequency, and duration of flood events in the Halifax River system.

Water Quality Improvement

Due to extensive drainage improvements in the Nova Canal basin, the pollutant discharge loading has increased to the Halifax River (Haydt and Frazel 2003). This has caused water quality and habitat degradation in the Halifax River estuary. The project is expected to improve water quality of the Halifax River but detailed modeling of historic, current, and post project conditions will be needed to quantify the impact of the project. The impact of the project on the water quality of Lake Hadley and on fishing will need to be studied.

Halifax Canal Horizontal Well Demonstration Project

The Halifax Canal horizontal well demonstration project is located at the intersection of Dunlawton Avenue and Spruce Creek Road. As part of this project a horizontal well was installed in a dry pond near the Halifax Canal by the city of Port Orange. A horizontal well recovery system is an alternative way for intake and filtration of surface water. The demonstration project will provide valuable information regarding potential well yield for stormwater recovery from the Halifax Canal. The project will also provide water quality information of the recovered water.

Future Work

This study is based on a planning level model which did not include a water quality component. Storage systems were not included in the project cost estimates; these will need to be added once a project sponsor is identified. Additional modeling work will be required to design structures and quantify water quality improvements. An operations plan or water control manual will need to be developed to manage the system and projects described in this study. Also required will be personnel to operate the system. First steps in implementation of any selected project should be to install the water control structure and to identify potential storage areas.

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Appendix A
Photographs of 11th Street Canal System (3/20/07)

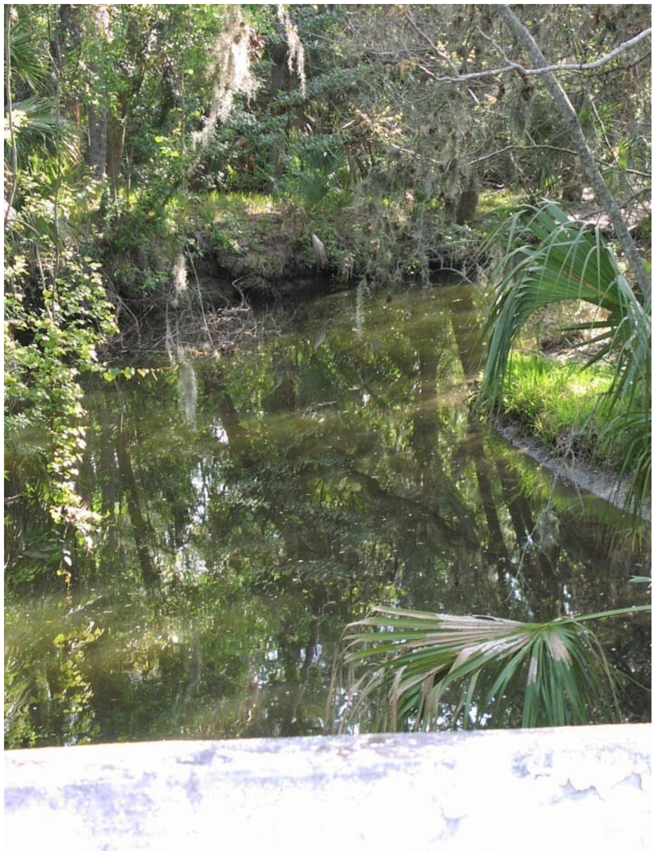

Figure A1. 11th Street Canal at Holly Hill

Figure A2. 11th Street Canal at Holly Hill

Figure A3. 11th Street Canal at Holly Hill

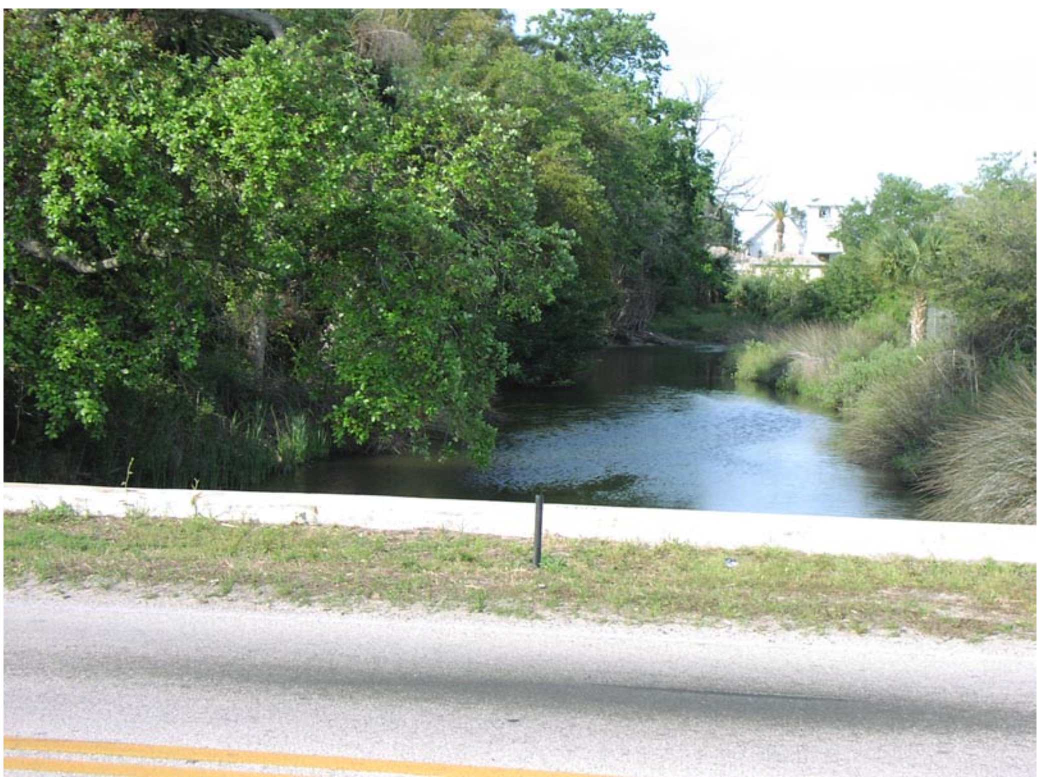

Figure A4. 11th Street Canal at A1A

Figure A5. 11th Street Canal at A1A

Figure A6. 11th Street Canal at US1

Figure A7. 11th Street Canal at junction with 10th Street Canal, looking east

Figure A8. 11th Street Canal at junction with 10th Street Canal, looking south

Figure A9. 11th Street Canal at junction with 10th Street Canal, looking south

Figure A10. 11th Street Canal at junction 10th Street Canal, looking west

Figure A11. 11th Street Canal, Centennial Park, looking north

Figure A12. 11th Street Canal, Centennial Park, South Ponds and Canal

Figure A13. Nova Canal at 8th Street, looking north

Appendix B
Photographs of Reed Street Canal System (3/20/07)

Figure B1. Ponds at Samuel Butts Youth Park

Figure B2. Reed Canal Stormwater Park

Figure B3. Stevens Canal Structure at junction with Reed Canal

Figure B4. Stevens Canal Structure looking south to junction with Reed Canal

Figure B5. Reed Canal at junction with Stevens Canal, looking east

Figure B6. Reed Canal at junction with Stevens Canal, looking west

Figure B7. Reed Canal at Rinker Ponds, looking north

Figure B8. Reed Canal at Rinker Ponds, looking north

Figure B9. Reed Canal at Rail Road tracks, looking west

Figure B10. Reed Canal at US1, looking west

Figure B11. Reed Canal at US1, looking west

Figure B12. Reed Canal at US1, looking east

Appendix C
Photographs of the Halifax Canal System (3/20/07)

Figure C1. Halifax Canal south of Orange Street

Figure C2. Halifax Canal at Bushman Park, looking north

Figure C3. Bushman Park, pump station

Figure C4. Halifax Canal at Bushman Park, looking south

Figure C5. Halifax Canal at Bushman Park

Figure C6. Bushman Park looking west to Halifax Canal

Figure C7. Bushman Park, Pump Station

Figure C8. Storage pond at Bushman Park

Figure C9. Pond with boardwalk and gazebo at Bushman Park

Figure C10. Port Orange Horizontal Well Demonstration site

Figure C11. Port Orange Horizontal Well Demonstration site

Figure C12. Halifax Canal at Port Orange Horizontal Well Demonstration site