Westhoff Engineering Resources, Inc.

APEGA Permit No.: P6305

Land & Water Resources Management Consultants

May 18, 2017

File: wer116-87-4900

Rocky View County
911 – 32 Ave NW
Calgary, AB T2E 6X6

Attention: **Gurbir S. Nijjar, P.Eng.**

Municipal Engineer

Subject: **Sub Catchment Drainage Plan for Fairways at Delacour**

Response to comments

This letter is to respond to the comment received by Westhoff Engineering resources, Inc. (Westhoff) from Rocky View County (RVC) by email on May 18, 2017 to the report "Sub Catchment Drainage Plan (SCDP) for Fairways at Delacour" prepared for McIntosh Tree Farms Inc.

The comment is that the total volume provided in treated wastewater ponds 18 and 19 is not sufficient according to the latest conceptual scheme which mentions 86,400 m^3 (seven months of storage for 410 m^3 per day of wastewater effluent produced).

To address your comment, we have increased the proposed pond volumes for Ponds 18 and 19 to adhere to the winter storage requirements. A wet portion of 0.5 meter is added to account for accumulation of sediments. Also, stormwater from catchments 11, 12, 15 and 19 is draining into Pond 19. From the single event analysis as presented in the SCDP report, a total of 4,840 m^3 is generated from these catchments during the 24 hour, 1:100 storm event.

As the continuous simulation model results as well as the single event analysis did not show any issues with the old pond configuration, both models are not updated for the larger volumes.

The updated pond tables are shown on the next page. The **active** volume of Pond 18 and pond 19 totals 88,660 m^3, which is sufficient to accommodate 4,840 m^3 storm runoff and 7 months of treated effluent (based on production of 410 m^3/day).

Attached to this letter is the updated SCDP for Fairways at Delacour.

Pond 18						
Elevation	**Depth**	**Area**	**Incremental Volume**	**Cumulative Volume**	**Active Volume**	
(m)	*(m)*	*(m^2)*	*(m^3)*	*(m^3)*	*(m^3)*	
6	0	4938	0	0	0	Bottom
6.5	0.5	5953	2720	2720	0	NWL
7	1	7041	3250	5970	3250	
8	2	9455	8250	14220	11500	
9	3	12259	10860	25080	22360	
10	4	15253	13760	38840	36120	
10.7	4.7	17118	11330	50170	47450	HWL
11	5	17982	5270	55440	-	Freeboard

Pond 19						
Elevation	**Depth**	**Area**	**Incremental Volume**	**Cumulative Volume**	**Active Volume**	
(m)	*(m)*	*(m^2)*	*(m^3)*	*(m^3)*	*(m^3)*	
6	0	2770	0	0	0	Bottom
6.5	0.5	4095	1720	1720	0	NWL
7	1	5574	2420	4140	2420	
8	2	8755	7160	11300	9580	
9	3	12166	10460	21760	20040	
10	4	15753	13960	35720	34000	
10.7	4.7	21041	12880	48600	46880	HWL
11	5	23407	6670	55270	-	Freeboard

Closure

Please note that the as-built drawings only confirm hydraulic conditions of the pond. We trust that the information submitted is complete to process approval. Should you have any questions or comments, please contact us.

Yours sincerely,

Westhoff Engineering Resources, Inc.

Lotte Veth
Water Management Specialist

Dennis R. Westhoff, M.Eng., P.Eng.
Chief Engineer - Water Resources

Enclosure	Pond 5 As-Built Drawing Set	
Cc:	Rod Sieker, P.Eng.	IBI Group
	Bruce Yorga	Lawson Projects

Westhoff Engineering Resources, Inc.

APEGA Permit No.: P6305

Land & Water Resources Management Consultants

May 4, 2017

File: wer116-87-4900

Rocky View County
911 – 32 Ave NW
Calgary, AB T2E 6X6

Attention: **Gurbir S. Nijjar, P.Eng.**

Municipal Engineer

Subject: **Sub Catchment Drainage Plan for Fairways at Delacour**

Response to comments

On March 14, 2017 Westhoff Engineering resources, Inc. (Westhoff) received comments from Rocky View County (RVC) by email to the report "Sub Catchment Drainage Plan (SCDP) for Fairways at Delacour" prepared for McIntosh Tree Farms Inc. On May 1, 2017 we had a meeting to go over the comments and responses and clarify any additional points. Based on the email and the meeting, the Sub Catchment Drainage Plan (SCDP) report has been updated based. Also, based on comments from the WID the concept plan has been slightly updated. These updates are represented in the updated SCDP as well, including:

- No ponds allowed in the canal right of way west: ponds 8, 9, 10 are removed from the concept plan. The volume is incorporated in pond 7.
- No ponds allowed in the canal right of way east: ponds 11, 12 and 15 are removed from the concept plan. Sub- Catchments 11, 12, 15 will now be directed to Pond 19.
- Updated land use areas based on the concept update.

Below and for ease of reference, we have repeated the comments and provided our responses in *italics*.

1. Comment: Please review findings of the Near Surface Groundwater testing report prepared by Almor Testing Services for inclusion into the report. The report currently uses the old data prepared by Sabatini Earth Tech dated July 2002; report has been attached.

   Response: The report has been reviewed and attached to the updated SCDP report.

2. Comment: Is there any map showing the extents of the external catchment areas draining to the culverts below Highway 791? Where does this water currently go? To the WID Canal?

Response: The map is added to the updated SCDP report as Figure 2, existing conditions. The runoff from these external areas is currently contained within the golf course. Prior to the development of the golf course the runoff drained into the WID Canal.

3. Comment: Is there any map showing only the existing ponds (golf course ponds)?

   Response: The map is included in the updated SCDP report as Figure 2, existing conditions.

4. Comment: Have the capacities of the existing ponds been field verified?

   Response: The capacities of the existing ponds have been verified by McIntosh Tree Farms Inc. when the ponds were constructed. The volume of existing ponds will be verified during detailed design and future ponds are to comply minimum with the provided volumes in the SCDP report.

5. Comment: As per the report, the WTP effluent winter storage emptying during the early spring season clears volume for stormwater runoff events in the springtime. What is to occur if the winter storage is not irrigated and there is less capacity in the ponds than contemplated in the report? Would the water quality after the winter months be sufficient to irrigate the golf course?

   Response: It is unlikely that the winter storage will not be used for irrigation. Wet spring conditions are modeled in the continuous simulation including wet and dry years. Also, no water is taken from WID until the winter storage is empty. Irrigation could start as early as in late March. The application for construction and operation of a wastewater system will generate an approval from AEP which will have conditions. Treated effluent quality has a much higher standard than irrigation water quality. There are many similar operations in Alberta and RVC is not liable.

6. Comment: Please increase imperviousness of multi-use/commercial to 90%

   Response: Noted. This has been updated in both the continuous and single event simulations as well in the updated SCDP report.

7. Comment: Should the ponds not be considered 100% impervious as rainfall falling in the pond areas is assumed to be directly conveyed to the pond (or near to 100% if there is green space above the HWL)

   Response: The pond water surface is considered 100% impervious in all the modeling. As the area on the slope of the pond between the simulated water level and the High Water Level (HWL) is varying due to inflow (runoff) and outflow (irrigation), the impervious ratio varies day by day.

8. Comment: Please assume green space to have some imperviousness (paved pathways and amenities)

   Response: The impervious ratio for greenspace has been updated to 5% to account for pathways and amenities. This has been updated in the models and the updated SCDP report.

9. Comment: Section 3.5 states that ponds will be lined. How will the existing storm ponds be lined?

Response: If required, the existing ponds can be emptied and provided with a liner. All future ponds will be lined.

10. Comment: Add label for Pond 6 to Figure 3

    Response: Figure 3 in the updated SCDP has been updated accordingly.

11. Comment: As some of the ponds have been combined and displayed in Table 3 (CN, NE, SE and SW), how will the individual parameters of the water bodies be determined within each of the combined ponds in Table 3? Are the sizes of these ponds arbitrary and to be determined by the civil designer to ensure that the sum of the parameters of the ponds are to match table 3?

    Response: Yes, more exact values for sub catchments and volumes of the ponds will be provided at the detailed design stage. For the SCDP report level the existing pond HWL area, depth and slopes are provided by the owner and volumes are calculated from this information, which will be verified at detailed design stage.

12. Comment: Are the parameters listed in table 3 relative to the bottom of the pond (elev. 0)? It appears that elev. 0 is near or at Pond 13. Can these values be updated to reflect the survey data and an actual datum?

    Response: The parameters shown in Table 3 are relative with the bottom of each pond at level 0 m. Pond 13, 16 and 17 are dry ponds and has no (upper or lower) NWL. From a modeling perspective, the actual levels are ignored as the stage-area-volume relationship is used for the computations.

13. Comment: Please add the labels of NWL, HWL and spill to tables 4 – 15 as it will be easier to see the storage volumes of the ponds at key levels

    Response: Tables 4-15 have been updated in the updated SCDP.

14. Comment: Where was the 409 m³ per day of treated wastewater effluent assumed? As per Table 19, 409 m³/day is the maximum WTP effluent rate based on requirements by AEP. It would be prudent to determine the number of proposed homes for this development to get an accurate volume of effluent to be expected to enter the system

    Response: The amount of treated wastewater inflow is based on 75 Imp Gallons per person per day. The development is expected to accommodate approximately 1200 residents. This results in 90,000 Imp Gallon/d or 409 m³/day. The number of 1200 residents is based on the conceptual scheme as prepared by Wescott Consulting Ltd.

15. Comment: Are the pumps assumed to turn on whenever the elev. in the pond is above the NWL?

    Response: The pumps will be managed by the golf course operator 24/7 and will optimize the capacity of the ponds. Float controls can be added.

16. Comment: Section 3.7 states that in situations where discharge is conveyed to the WID, the WID water quality standards may govern depending on the timing of release of stormwater. Where in the concept does water from the storm system enter the WID canal system? Then it states

that this is a zero release system and no TSS is being released. Is TSS of any concern in this drainage concept?

*Response: There is **no** release into the WID system. TSS is of no concern for the development as there is no discharge to receiving waterbody and no measures such as oil and grit separators are required. The TSS will be captured in the ditches and the onsite ponds. The pumps will have a filter so no fine materials will clog the pumping systems.*

17. Comment: Has any high level consideration been given to the water quality in the irrigation ponds due to the wastewater effluent? How was this taken into consideration?

    Response: No, the waste water treatment plant will be designed to produce treated effluent standards and meet irrigation standards.

18. Comment: Section 4.1.1 states that infiltration was assumed in the model. Previous portions of the SCDP report state that ponds are to be lined

    Response: The Horton's infiltration parameter is used in the PCSWMM model, this is the infiltration rate for the pervious areas to the subsurface. The ponds are assumed to be lined and no infiltration is calculated.

19. Comment: Has the irrigation schedule been discussed with the golf course owner? Golf courses are known to be balance of water management and irrigation throughout their season and tend to have a large demand for irrigation supply. The irrigation values in Table 16 may not be sufficient to supply the golf course making the sizing of the ponds conservative

    Response: The golf course has provided the irrigation totals of the years 2011 to 2015 averaging about 160,000 m^3 per year. This yearly irrigation supply volume is reflected in the water balance modeling. In dry years water could be diverted from the WID (see also next comment).

20. Comment: Has the model taken into account the purchase of water from the WID to be stored in the irrigation ponds? This may have impact to the active storage of the irrigation ponds. This is very typical for golf courses

    Response: The golf course has a license to divert water from the WID Canal. In case water from the WID Canal would be required for irrigation purposes, the water is directly used. There will be no storage of WID Canal water in the ponds.

21. Comment: We have seen in other developments in the County that irrigation of stormwater containing effluent is only permitted in off hours where the public does not have access to the site. Has this been considered or impact the modelling in any way?

    Response: Yes, typically, the irrigation of the golf course takes place at night and in the early morning. In the WWB model this has been incorporated as a certain amount of the water needs to be irrigated daily. The operational irrigation schedule will be determined by the irrigation contractor.

22. Comment: Would it be possible to make an assumption in the PCSWMM modelling for the added volumes of the wastewater effluent and irrigation water from the WID? Essentially beginning the modelling assuming there is more water in the pond.

Response: As responded above to previous comments the likelihood of the treated wastewater not being irrigated is low and there is no storage of WID Canal water within Central Pond. However, in the SCDP report on Page 26 an extreme situation analysis is described (in paragraph 5.1, this paragraph number has been changed to 5.2 in the updated SCDP report) and the results show that only the golf course would be inundated; ***no*** *stormwater would be released to the WID Canal.*

The analysis assumes the two main ponds (Pond 2 and Central Pond) are full up to the HWL and a subsequent 1:100 year 24 hour storm event would occur. This extreme scenario was analyzed in PCSWMM. To fill up the two main ponds up to HWL only happens during a 1:300 year design storm event with total precipitation equal to 104 mm. The inundation extent that would occur in such an extreme situation is shown in Figure 5; the ponds would flood, but the inundation extent would be retained within the golf course.

For the detailed design, it is recommended that the freeboard for both ponds and surrounding areas would provide capacity to store runoff from a 1:500 year design storm event.

23. Comment: Any idea of the how high the berms on both sides of the WID canal need to be from a conceptual level to prevent spillage of water in case the ponds overflow?

Response: As noted previously, adequate storage capacity is provided and berms would not be required to contain runoff from a 1:500 year event.

24. Comment: No overflow events are recorded in either of the simulation events however wouldn't the pumps still function (conveying water between ponds) during the rain events?

Response: The ponds are designed have enough volume to handle the 1:100 year 24 hour storm event. Yes, the pumps will be functioning during storm events.

25. Comment: Can you further explain what types of risk analyses can be carried out at the detailed design stage to ascertain the estimation of various design values?

Response: The risk scenario's that can be evaluated are:

- *Drought scenario during which time diversion from the WID is triggered*
- *Wet weather scenario albeit that a most extreme scenario has already been evaluated – see response 22*
- *Pump failure noting that replacement and spare parts are onsite.*

Closure

We trust that the response submitted with this letter and the attached updated SCDP report is sufficient to process the approval. Should you have any questions or comments, please contact us.

Yours sincerely,

Westhoff Engineering Resources, Inc.

Lotte Veth
Water Management Specialist

Dennis R. Westhoff, M.Eng., P.Eng.
Chief Engineer - Water Resources

Cc:	Doug McIntosh	The Canal at Delacour
	Robert Wescott, AICP	Wescott Consulting Group
Enclosed:	Updated Sub Catchment Drainage Plan for Fairways at Delacour	

Sub Catchment Drainage Plan for Fairways at Delacour

Prepared by:

Westhoff Engineering Resources, Inc.

Land & Water Resources Management Consultants

Sub Catchment Drainage Plan for Fairways at Delacour

Issued for approval

April 4, 2017

Prepared for:

McIntosh Tree Farms Inc.

File: 116-87

Prepared by:

Westhoff Engineering Resources, Inc.

Suite 601

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Corporate Authorization

This document entitled Sub Catchment Drainage Plan for Fairways at Delacour was prepared by Westhoff Engineering Resources, Inc. It is intended for the use of McIntosh Tree Farms Inc. and approval authorities for which it has been prepared. The contents of the report represent the best judgment of Westhoff Engineering Resources, Inc. based on information available at the time of preparation. Any use a third party makes of the report, or reliance on or decisions made based on it, are the responsibilities of such third parties. Westhoff Engineering Resources, Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on the report.

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APEGA Permit No. P6305

Corporate Permit

Responsible Engineer

Analysis and Report preparation by Lori Hu, P.Eng., Lotte Veth, M.Sc., and Jian Huang, Ph.D., E.I.T.

Analysis reviewed by Veerakcuddy Rajasekaram, Ph.D., P.Eng.

Report reviewed by Dennis Westhoff, M.Eng., P.Eng.

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1 Introduction

Westhoff Engineering Resources, Inc. (Westhoff) has been retained by McIntosh Tree Farms Inc. to prepare a Sub Catchment Drainage Plan (SCDP) to support the Fairways at Delacour Conceptual Scheme.

Around the existing Canal at the Delacour Golf Course, residential and some commercial development are proposed. As shown in Figure 1, the development named as the "Fairways at Delacour" (hereafter referenced as the "Project Site") is located in Rocky View County (RVC) in the quarter sections NW19-25-27-W4M and SW19-25-27-W4M. The Project Site currently comprises the Canal at Delacour Golf Course, the WID Canal and agricultural and country residential lands.

The Project Site is bordered by Secondary Highway 564 (north), Canadian National Railway (CNR) right-of way (northwest) and Secondary Highway 791 (west). The Western Irrigation District (WID) Canal bisects the Project Site from north to south.

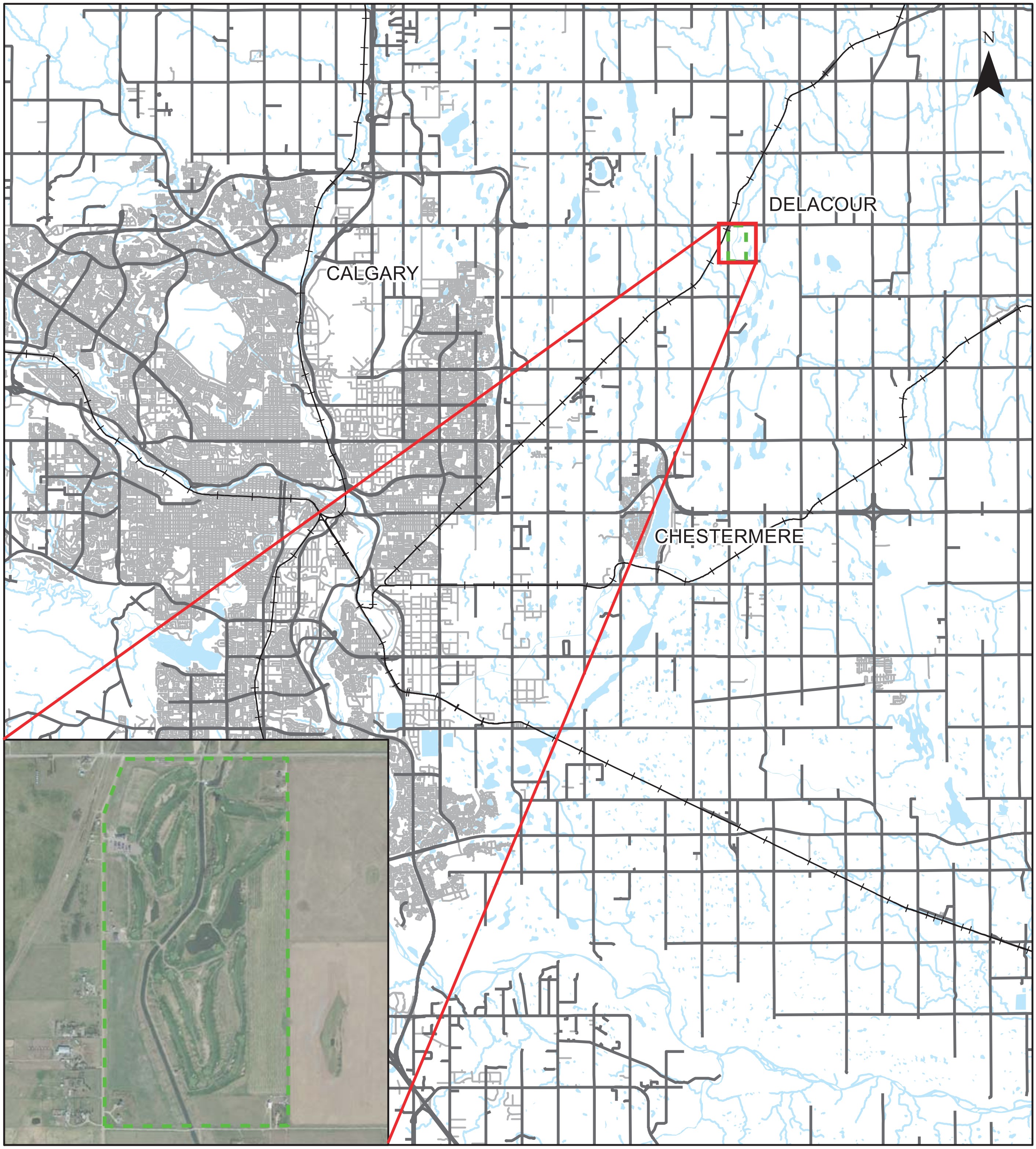
1.1 Objectives

The objectives of this SCDP are to present a stormwater management plan and implementation strategy for the proposed development. The development is traversed by a WID Canal; however, the concept is to be developed with no disturbance to the WID. This is achieved by designing the system so that:

- Zero-runoff to the WID Canal under conditions up to a 1:100 year, 24 hour storm event; and
- Use the captured runoff for irrigation of the golf course and the open space.

This SCDP adheres to the 2013 RVC Servicing Standards (Rocky View County, 2013). In addition, the report addresses concerns raised by the WID as outlined in the MPE letter, dated June 7, 2016, where applicable at this level of reporting.

It should be recognized that the SCDP is at a preliminary engineering level. Details will be presented when detailed engineering designs are developed and documented in the Stormwater Management Report (SWMR) and Pond Report.



LEGEND

- Project Site
- Major Road
- Minor Road
- Railway
- Water Body

Client:	MCINTOSH TREE FARMS, INC.
Project:	SUB CATCHMENT DRAINAGE PLAN FOR FAIRWAYS AT DELACOUR
Title:	PROJECT LOCATION

Date:	Project No.:	Scale:	
21-12-2016	WER116-87	1:250,000	**FIGURE: 1**

Westhoff Engineering Resources, Inc.
Land & Water Resources Management Consultants

1.2 Methodology

The following methodology was used to conduct the study:

- Collect all relevant information, including topographic mapping, concept development plans, and land use drawings;
- Review available geotechnical reports;
- Review available Biophysical Overview (BIO) and Biophysical Impact Assessment (BIA) reports;
- Delineate the pre development catchment and sub-catchment areas based on the received topographic information and proposed land use information. From the planner Wescott Consulting Group Ltd. (Wescott) 1m contour data was collected for the Project Site. Also, 15meter LIDAR data was downloaded for the delineation of external areas;
- Check size of proposed stormwater management facilities;
- Determine the overland flow path and direction of flow from private lots to stormwater storage facilities;
- Determine imperviousness ratios based on land use planning characteristics;
- Determine criteria and operational procedures to manage stormwater under zero-discharge conditions;
- Conduct post-development rainfall runoff analysis of the development area using single event and continuous simulation techniques. Update the single event analysis for the updated development concept performed using PCSWMM. The continuous simulation analysis is performed using Westhoff Water Balance Model designed for this specific development;
- Prepare recommendations for the detailed design of the future stormwater management system within the development;
- Summarize findings in the SCDP report.

1.3 Previous Studies

Relevant studies reviewed for the purposes of this report:

- Groundwater Assessment for Canal Golf Course, Sabatini Technologies Inc., 2002;
- Delacour Community Area Structure Plan, Rocky View County, 2005;
- Stormwater Management Study, Cicon Engineering Ltd., 2013;
- Fairways at Delacour Conceptual Scheme, Westcott Consulting Group Ltd., 2016.

- Shallow Subsoil and Groundwater Site Investigation, Almor Testing Services, Ltd., December 2016.

1.4 Approvals

Approvals from Rocky View County and Alberta Environment and Parks (AEP) under the *Water Act* and the *Environmental Protection and Enhancement Act* will be required prior to construction.

2 Existing Conditions

2.1 Site Description

The Project Site is approximately 127 hectare (315 acre) in size and is generally sloped towards the WID Canal that bisects the Project Site from north to south. Slopes vary from 2% (east) to 5% (southwest). The ground elevation varies from a high of approximately 1026m (southwest) to 1006 meters north around the WID Canal. The lands are currently used predominantly for the golf course, agriculture and country residential use.

There are two cross grade culverts along the Secondary Road 791. The culverts allow for runoff from external areas west of the Project Site to drain to the Project site.

2.2 Topography and Catchment Areas

The existing topography was evaluated from 1 m contour data received from Wescott. Figure 2 shows the existing catchments areas delineation within the site as well as the locations where external catchment areas connect to the Project Site.

Two external catchment area currently draining through the Project Site into the WID Canal. These areas were delineated in a previous study by Cicon Engineering Ltd. (2013). Based on LIDAR 15 meter data the boundaries were verified and adjusted where necessary.

The largest external area (total 142.8 ha) originates NW of the Project Site and comprised agricultural lands. The drainage from this area crosses Secondary Highway 564 and CN rail through culverts and enters the Project Site via a culvert under Secondary Highway 791.

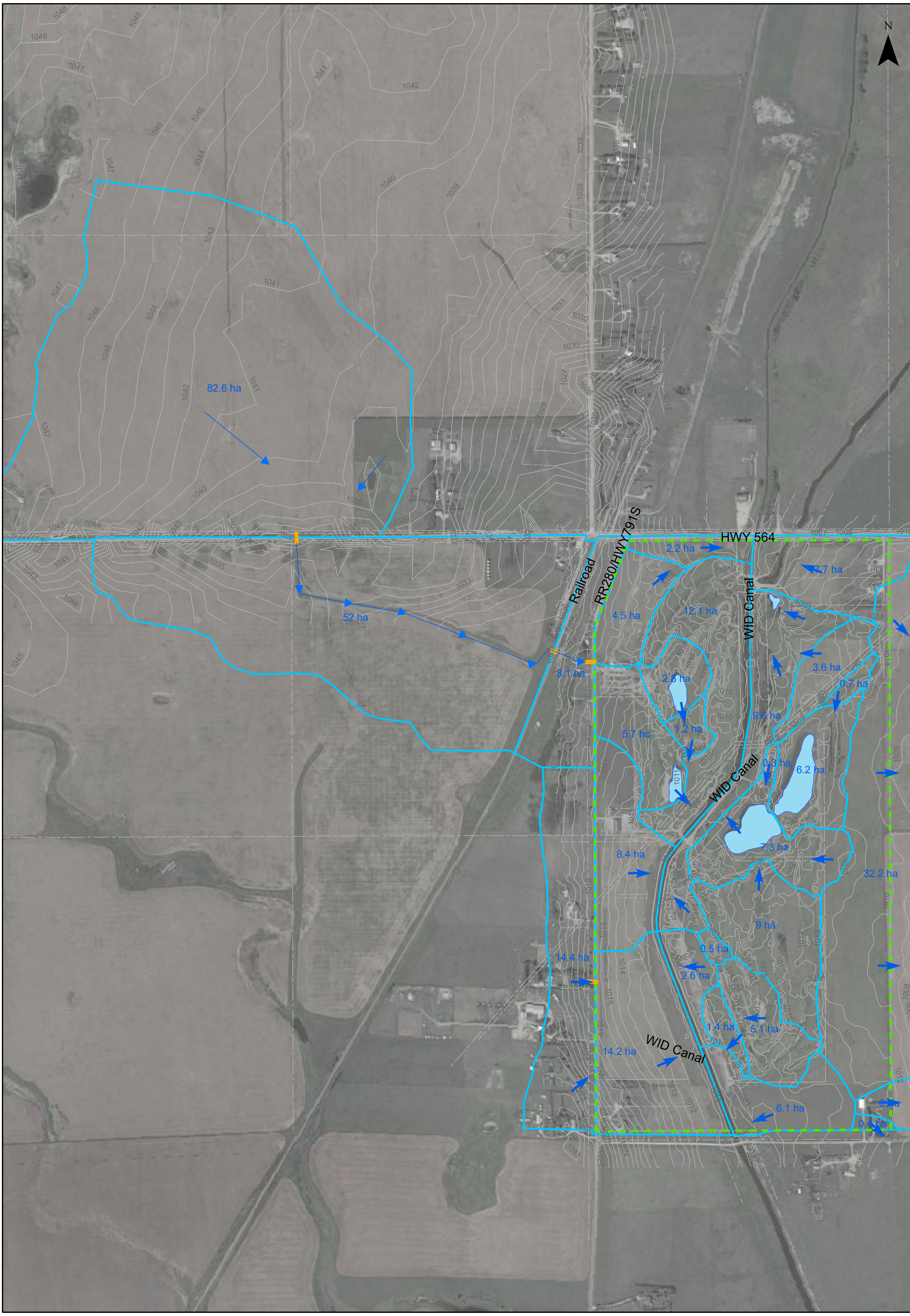
The second external area is located west and enters the Project Site via a culvert under Secondary Highway 791.

2.3 Soil and Groundwater

A Shallow Subsoil and Groundwater Site Investigation was conducted by Almor Testing Services, Ltd. in December 2016. Eight test holes were drilled and monitored. The subsurface conditions observed in the boreholes for the Project Site are relatively uniform and typically silty clay till overlying bedrock. Bedrock described as mudstone was encountered at variable depths in all test hole locations. A silty sand deposit was encountered within four of the boreholes. Monitored groundwater levels indicate that groundwater will not have an impact on the site grading operations to a depth of 2 to 4 meter.

2.4 Wetlands

No Biophysical Impact Assessment (BIA) was available for the Project Site.



Legend

- Drainage Direction
- Existing Culvert
- Existing Pond
- Sub- Catchment Area Predevelopment
- Existing Contours (1m)
- Legal Plan
- Project Site

Client:	MCINTOSH TREE FARMS INC.
Project:	SUB CATCHMENT DRAINAGE PLAN FOR FAIRWAYS AT DELACOUR
Title:	EXISTING TOPOGRAPHY

Date:	Project No.:	Scale:	
23-03-2017	WER116-87	1:10,000	FIGURE: 2

Westhoff Engineering Resources, Inc.
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3 Stormwater Management Concept

3.1 Proposed Drainage Concept

The Project Site is challenged from a drainage perspective due to the WID Canal and the large external areas draining onto the site. The proposed stormwater management system embraces the Low Impact Development (LID) approach and focusses on the capture of runoff for irrigation use purposes.

Irrigation season for the Golf Course exceeds the WID Canal operation schedule. Especially in the weeks prior to the opening of the WID Canal season the golf course requires a large quantities of irrigation water.

The waste water of the development is proposed to be pumped to a local Water Treatment Plant (WTP). The waste water will be treated to irrigation water quality standards and collected into the ponds and used for irrigation. The WTP effluent winter storage emptying during the early spring season clears volume for stormwater runoff events in the springtime.

The goal of this study is to balance the runoff from the development and external areas, the WTP effluent and irrigation of the Golf Course.

Figure 3 shows the proposed stormwater management concept for the Project Site. The proposed drainage system comprises:

- A major overland conveyance system leading to the stormwater storage facilities, generally following the open space and road network system;
- 14 existing and proposed stormwater storage facilities connected to the central storage pond through gravity pipes/swales where possible and via a pump and forcemain where needed;
- Two WTP effluent storage ponds connected to the central storage pond by via a pump and forcemain;
- A central stormwater pond that serves as intake for the irrigation system of approximately 53 ha of Golf Course;

Drainage from individual lots shall include LID and BMP measures and initiatives to control release rates and volumes reaching the conveyance system leading to the stormwater storage facilities. The road side ditches will be vegetated to enhance treatment by filtering suspended solids and will be designed to safely convey all storm events up to the 24 hour, 1:100 year storm. The stormwater storage facilities will act as forebays to provide settling of suspended solids before discharged to the central pond. The design of the overland drainage features will be performed at the Detailed Engineering stage.

3.2 Land Use

The Concept Plan provided by Wescott on December 8, 2016, identifies the land use composition for the Project Site. The land use composition forms the framework for determining stormwater management strategies, stormwater runoff volumes, and sizing of the associated stormwater storage facilities. In Table 1 the proposed land-use areas are presented along with the imperviousness ratio for each land-use type.

The proposed drainage concept along with various land-uses is presented in Figure 3.

Table 1: Proposed Land Use Assumptions

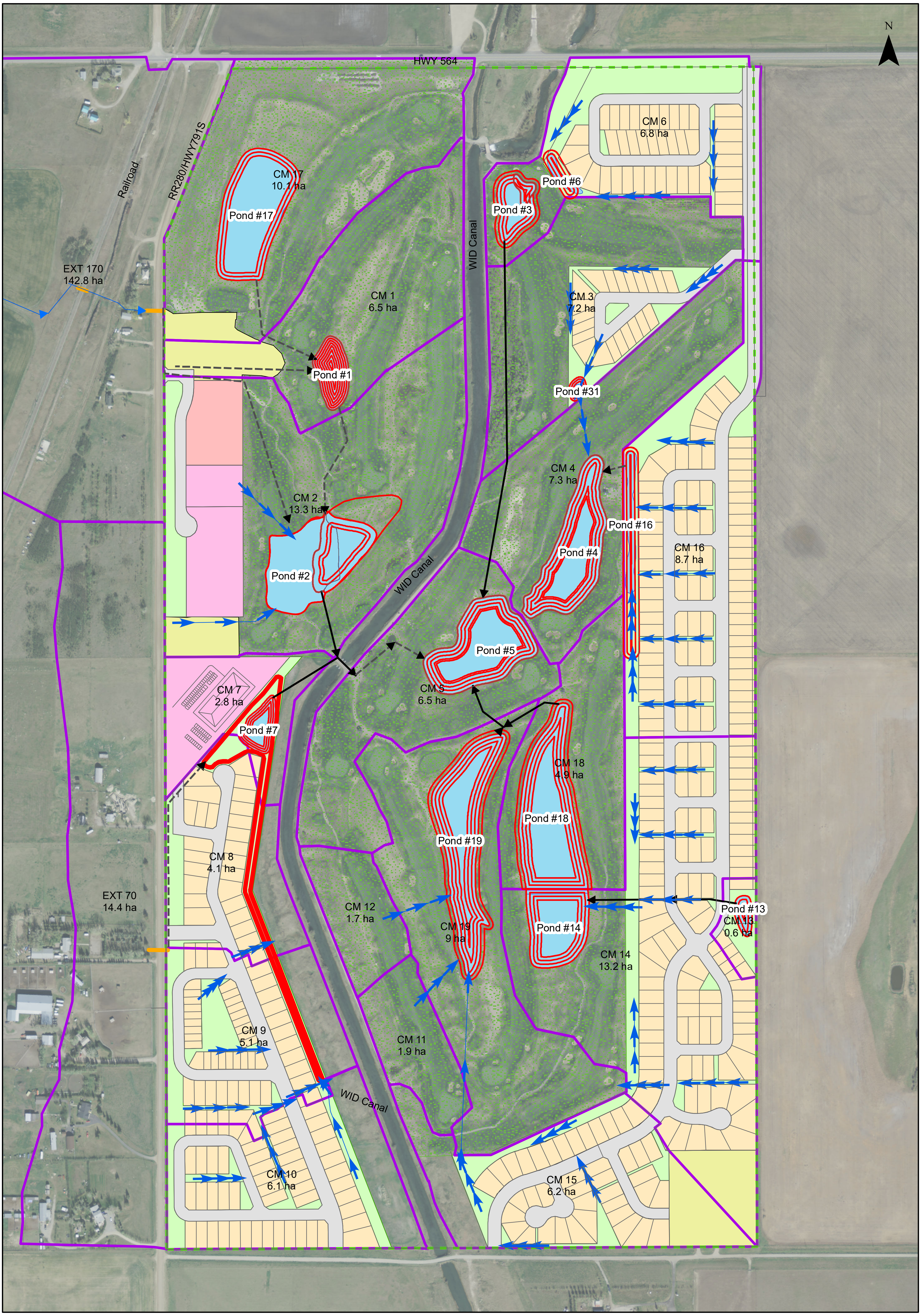
Land Use	Area (ha)	Imperviousness Ratio (%)
Lots	23.3	60
Multi-Family/Senior	3.2	70
Commercial	0.8	90
Roads	10.3	100
Existing County Residential	3.3	5
Golf course	56.5	5
Open Space	14.6	5
Ponds	10.2	100
Total Area	**122.2**	

3.3 Post Development Catchment Areas

Post development catchment areas are defined by the anticipated layout of development as no proposed grading plans were made available. The Project Site has been sub-divided into 21 sub-catchment areas corresponding to the existing and proposed ponds. The proposed catchment boundaries are also illustrated in 3 and a summary of the individual catchment areas is presented in Table 2.

Table 2: Proposed Catchment Areas

Landuse	Catchment Area (ha)																				
	CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8	CM9	CM10	CM11	CM12	CM13	CM14	CM15	CM16	CM17	CM18	CM19	EXT70	EXT17 0
Lot	0.0	0.0	1.0	0.0	0.0	2.4	0.0	1.7	2.1	2.9	0.0	0.0	0.2	5.8	2.7	4.7	0.0	0.0	0.0	0.0	0.0
Multi-Family/ Senior	0.0	1.6	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Commercial	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Roads	0.0	0.4	0.5	0.0	0.0	1.4	0.0	0.8	0.9	1.1	0.0	0.0	0.1	2.0	0.9	2.1	0.0	0.0	0.0	0.0	0.0
Existing County Residential	0.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.0	0.4	0.0	0.0	14.4	142.8
Golf course	5.4	8.0	5.0	6.0	5.3	0.8	0.1	0.0	0.0	0.0	1.9	1.7	0.0	2.5	0.4	0.0	8.3	3.4	7.6	0.0	0.0
Open Space	0.0	0.7	0.7	0.0	0.0	1.9	0.8	1.7	2.1	2.0	0.0	0.0	0.2	1.3	1.5	1.7	0.0	0.0	0.0	0.0	0.0
Pond	0.3	1.3	0.0	1.2	1.2	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.8	0.0	0.2	1.3	1.5	1.4	0.0	0.0
Total	**6.5**	**13.3**	**7.2**	**7.3**	**6.5**	**6.8**	**2.8**	**4.1**	**5.1**	**6.1**	**1.9**	**1.7**	**0.6**	**13.2**	**6.2**	**8.7**	**10.1**	**4.9**	**9.0**	**14.4**	**142.8**



Legend

Land Use (Concept Updated March 2017)	Pond Connectors (Conceptual)	Drainage
COMMERCIAL	Drainage Direction	Existing Culvert
EXISTING	Forcemain	Drainage Path/Direction
GOLFCOURSE	Gravity Pipe	Post Development Catchment Boundary
LOT	Proposed Pond Contour	Project Site
MULTI-USE/SENIOR		
OPEN SPACE		
POND		
ROAD		

Client: MCINTOSH TREE FARMS INC.

Project: SUB CATCHMENT DRAINAGE PLAN FOR FAIRWAYS AT DELACOUR

Title: DRAINAGE CONCEPT AND LANDUSE

Date:	Project No.:	Scale:	
23-03-2017	WER116-87	1:5,000	FIGURE: 3

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3.4 Management of stormwater from external areas

It is anticipated that the two external catchment areas will contribute runoff volumes to the Project Site. The flows from the external areas will be captured in Pond 7 (External area 14.4 ha) and Pond 2 (External Area 142.8 ha). These ponds will be sized accordingly.

3.5 Stormwater Ponds

Ponds will be lined according to Rocky View County's standards. In Table 3 the area at HWL, volume at HWL, and active volume of the proposed stormwater facilities are summarized.

Pond characteristics are summarized in Tables 4 to 14. A minimum of 30 cm freeboard is provided above HWL. The permanent water depth is varies from 0 m (dry ponds), 0.5 m (treated effluent ponds) and 1 m (wet ponds). The active storage depth for the ponds varies between 1 and 5.7 meter. It is noted that all ponds have capacities to spill beyond their perimeter onto the golf course with little to no damage.

Table 3: Basic Parameters of Ponds

Pond	LNWL (m)	UNWL (m)	HWL (m)	Volume at HWL (m^3)
Pond 1	2.0	2.0	6.7	8,900
Pond 2	0.5	0.5	3.6	27,950
Pond 13	0.0	0.0	1.75	830
Pond 14	1.0	1.0	2.7	16,950
Pond 16	0.0	0.0	1.75	5,050
Pond 17	0.0	0.0	1.0	10,170
Pond 18	0.5	0.5	4.7	50,170
Pond 19	0.5	0.5	4.7	48,600
Pond CN	0.5	3.5	3.5	50,910
Pond NE	1.0	1.0	2.0	5,440
Pond 7-SW	1.0	1.0	4.3	15,130

Pond CN is a combination of Pond 4 and Pond 5 and Pond NE is a combination of Pond 3 and Pond 6. Ponds 18 and 19 are used for treated effluent storage during the winter time.

The Depth-Area-Volume relationship for the individual ponds is provided in Table 4 through Table 14. Slopes between NWL and HWL are 3:1 for existing ponds and 5:1 for proposed ponds.

Table 4: Depth-Area-Storage Relationship for Pond 1

Elevation (m)	Depth (m)	Area (m^2)	Total Storage Volume (m^3)	
10	0	38	0	Bottom
11	1	248	140	
12	2	592	560	NWL
13	3	1025	1370	
14	4	1530	2650	
15	5	2099	4460	
16	6	2724	6880	
16.7	6.7	3066	8900	HWL

Table 5: Depth-Area-Storage Relationship for Pond 2

Elevation (m)	Depth (m)	Area (m^2)	Total Storage Volume (m^3)	
7	0	4078	0	Bottom
7.5	0.5	4948	2260	NWL
8	1	5818	4950	
9.7	2.7	9382	17870	
10.3	3.3	10781	23920	HWL

Table 6: Depth-Area-Storage Relationship for Pond 13

Elevation (m)	Depth (m)	Area (m^2)	Total Storage Volume (m^3)	
0	0	69	0	Bottom
1	1	462	270	
1.75	1.75	1046	830	HWL

Table 7: Depth-Area-Storage Relationship for Pond 14

Elevation (m)	Depth (m)	Area (m^2)	Total Storage Volume (m^3)	
7	0	360	0	Bottom
8	1	4910	4260	NWL
9	2	6380	9900	
9.7	2.7	7212	14660	HWL

Table 8: Depth-Area-Storage Relationship for Pond 16

Elevation (m)	Depth (m)	Area (m^2)	Total Storage Volume (m^3)	
7	0	290	0	Bottom
8	1	3049	1670	
9	2	5966	6180	HWL

Table 9: Depth-Area-Storage Relationship for Pond 17

Elevation (m)	Depth (m)	Area (m^2)	Total Storage Volume (m^3)	
16	0	9098	0	Bottom
17	1	11233	10170	HWL

Table 10: Depth-Area-Storage Relationship for Pond 18

Elevation (m)	Depth (m)	Area (m^2)	Total Storage Volume (m^3)	
6	0	4938	0	Bottom
6.5	0.5	5953	2720	NWL
7	1	7041	5970	
8	2	9455	14220	
9	3	12259	25080	
10	4	15253	38840	
10.7	4.7	17118	50170	HWL
11	5	17982	55440	Freeboard

Table 11: Depth-Area-Storage Relationship for Pond 19

Elevation (m)	Depth (m)	Area (m^2)	Total Storage Volume (m^3)	
6	0	2770	0	Bottom
6.5	0.5	4095	1720	NWL
7	1	5574	4140	
8	2	8755	11300	
9	3	12166	21760	
10	4	15753	35720	
10.7	4.7	21041	48600	HWL
11	5	23407	55270	Freeboard

Table 12: Depth-Area-Storage Relationship for Pond CN (4+5)

Elevation (m)	Depth (m)	Area (m^2)	Total Storage Volume (m^3)	
5	0	8988	0	Bottom
5.5	0.5	9871	4720	
6	1	10753	9870	
7	2	14938	22720	
8	3	19504	39940	
8.5	3.5	24401	50910	HWL

Table 13: Depth-Area-Storage Relationship for Pond NE (3+6)

Elevation (m)	Depth (m)	Area (m^2)	Total Storage Volume (m^3)	
3	0	1488	0	Bottom
4	1	2521	2000	
5	2	4355	5440	HWL

Table 14: Depth-Area-Storage Relationship for Pond SW

Elevation (m)	Depth (m)	Area (m^2)	Total Storage Volume (m^3)	
7	0	591	0	Bottom
8	1	1558	1075	
9	2	2857	3280	
10	3	4400	6910	
10.1	3.1	6995	7480	
11	4	12719	16350	
11.3	4.3	14465	20430	HWL

3.6 Water Transfer between Ponds

Water transfer between ponds is carried out using gravity pipe/swales or pump and forcemain systems, as appropriate. Figure 4 shows the schematic of catchments, ponds and the water transfer plan. As of this preliminary design stage, the gravity system is assumed to be swale with appropriate capacity. The capacities of pumps operated between ponds are derived using the single event and continuous simulation analysis as described in Section 4.

The treated waste water effluent is captured within Ponds 18 and 19. As of this preliminary design, 50% of effluent is assumed captured in each pond.

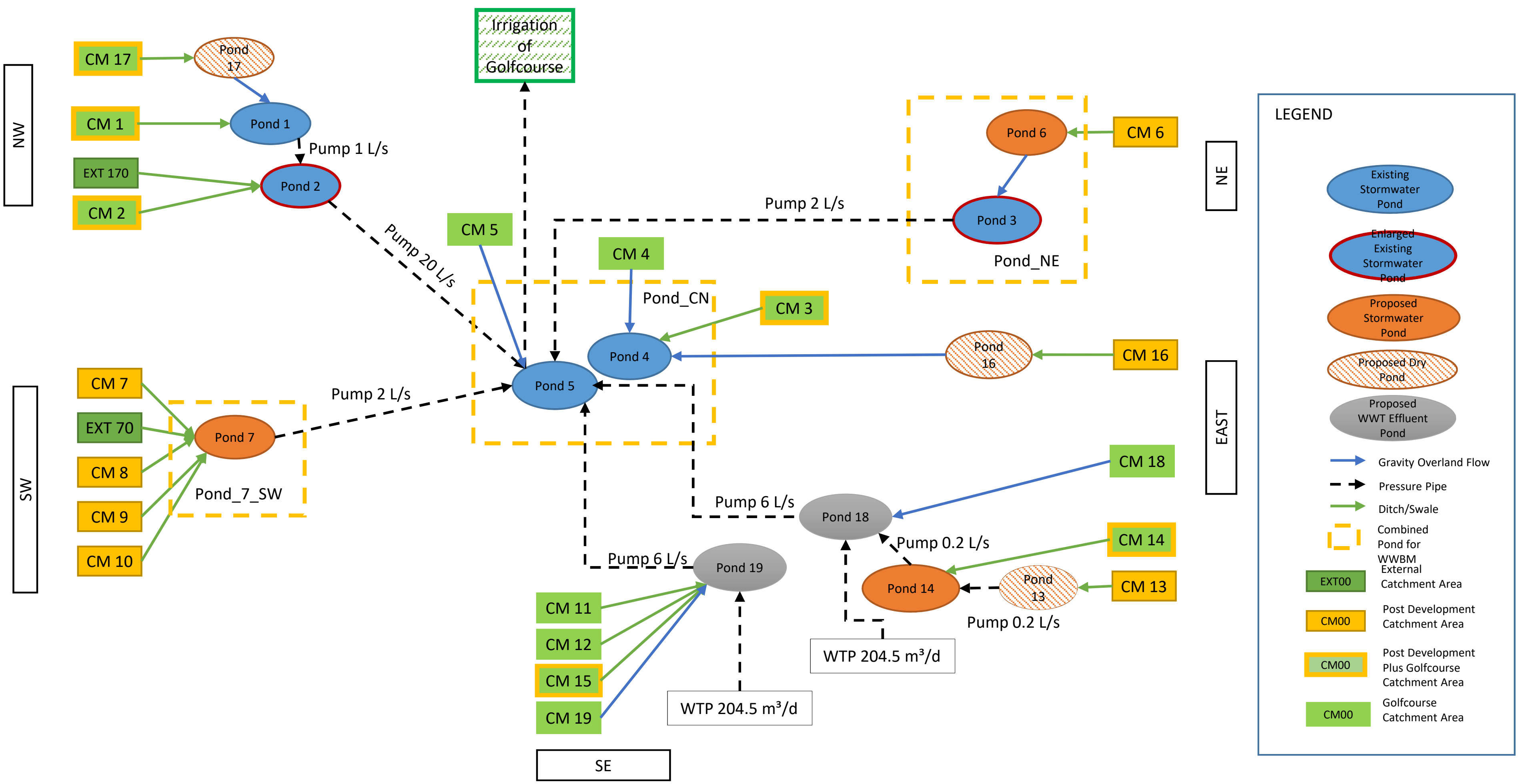
The irrigation requirement of all golf course and lawns in the development lots is assumed to be supplied from the central pond Pond CN.

3.7 Water Quality Aspects

Alberta Environment requires 85 percent annual removal of Total Suspended Solids (TSS) for particles of 75 microns in size or larger. Therefore, all runoff from the study area should reach the stormwater storage facility where the suspended solids can settle. The City of Calgary requires that 85% of 50 micron particles or larger be retained. Rocky View County requires that the more stringent water quality requirement be followed. RVC follows the City of Calgary standards, therefore this requirement is taken into account for this project. In situations where discharge is conveyed to the WID, the WID water quality standards may govern depending on the timing of release of stormwater. Considering that the development operates as a zero-discharge development, there is simply no TSS being released into receiving streams.

In order to provide the irrigation system with filtered water as much as possible a treatment train process is proposed. That is, water quality is improved by incorporating grassed overland drainage ditches and roadside ditches leading to the ponds where TSS will settle before the water is pumped to the Central Pond (Pond CN).

Figure 4: Schematic of Catchments, Ponds and Water Transfer Plan



4 Hydrology and Continuous Simulation Modeling

The precipitation-runoff simulation within urban areas is analyzed using single event and/or continuous simulation techniques. Preliminary pond sizing for instantaneous peak runoff has been analyzed using PCSWMM. The performance of various source control practices and stormwater management facilities is analyzed using the special formulation of Westhoff Water Balance Model (WesthoffWB).

The set-up of the computer models was accomplished by determining model parameters for catchment including size, imperviousness ratios, and infiltration characteristics. Stormwater storage capacities for the site for a 1:100 year, 24 hour storm event and continuous simulation were determined in successive simulation runs. The larger resulting storage requirement from either the single event or continuous simulation will govern.

4.1 Single Event Analysis

The most common method of analysis used for stormwater management is based on a single storm event; either a real historic storm or a theoretical design storm. Single event analysis and design is an accepted procedure as outlined in the Guidelines for Stormwater Management in the Province of Alberta (1999). Therefore, this method is used in this study.

The aforementioned guidelines require that the major drainage system, including storage facilities, shall be designed to accommodate the runoff resulting from a 1:100 year return period storm event. Accordingly, the 24 hour duration, 1:100 year design storm event of the Chicago distribution was used for this study. The distribution represents two important design criteria:

- The total precipitation of the Chicago storm, for any duration, is the same as the total precipitation defined for the 1:100 year event.
- The peak intensity of the Chicago storm, for any time increment, is the same as the peak intensity defined for the 1:100 year event.

A total storm duration of 24 hours with 5 minute rainfall increments was used, based on the Intensity-Duration-Frequency (IDF) relationship for the City of Calgary and as provided by Atmospheric Environmental Services (AES).

Rainfall intensities for the Chicago distribution are determined from the IDF relationship and described as:

$i = a/(t+b)^c$ .... [1]

where i is intensity (mm/h), a, b and c are IDF parameters and t is the time duration (minutes).

The time to storm peak is determined by:

$t_p = r(t_d)$ .... [2]

where t_p is the time to peak and r is the ratio of time to peak versus storm duration, t_d.

The following parameters were used to derive the rainfall intensities for this design storm, which are based on the IDF data for the City of Calgary.

a = 663.1
b = 1.87
c = 0.712
r = 0.3

4.1.1 PCSWMM-based Modeling Analysis

The PCSWMM model was used to verify that active storage is available in the proposed stormwater ponds. For this model, the required parameters (See Appendix A) were input for the computation of maximum volume requirements for the 1:100 year, 24 hour storm event. Horton's infiltration model was applied with the parameters recommended by the City of Calgary (City of Calgary 2011). As this analysis was performed for single event purposes these infiltration parameters were found to be sufficient. The model schematic, input parameters and the output are summarized in Appendix A.

Additionally an extreme event analysis is performed to present the inundation extent in such case. The 1:100 year, 24 hour storm event is run when the two main ponds (Pond 2 west of the Canal and Pond Central (Ponds 4 and 5) and the east side) are at HWL.

4.2 Water Balance Analysis – Continuous Simulation

Westhoff has developed a customized water balance model to simulate the proposed site conditions based on a historical meteorological record over a 56 year time frame, 1960 – 2015. The GoldSim modelling software was used to develop the Westhoff Water Balance (WesthoffWB) model. The water balance analysis is set up to consider the post-development conditions for the existing and proposed stormwater facilities.

The water balance analysis uses a daily time step. Daily evaporation and evapo-transpiration time series, developed using meteorological data, was used to represent the evaporation losses from the stormwater ponds and wetted areas. Sublimation losses related to snowpack are conservatively to be equal to 10% of precipitation over the winter months.

GoldSim allows for programming of complex systems for a variety of operational procedures introduced to model individual developments based on the unique characteristics of the development. Due to the flexibility of the program, the Fairways at Delacour development has been modeled to replicate how the system is intended to function by incorporating LID initiatives and BMP. Creating and testing the ultimate configuration at the SCDP level will assist in the planning and engineering of phased development as the project proceeds.

The water balance analysis considers the following aspects to reuse the runoff generated from the catchment area:

- Supply of water from Central Pond (Pond CN) for the purpose of irrigation of the Golf Course;
- WTP effluent of 204.5 m³/day applied to Pond 18 and 204.5 m³/day applied to Pond 19;
- Proposed pump capacities; and,
- Proposed gravity swale parameters.

4.2.1 Irrigation Schedule

The golf course area is assumed to be irrigated according to a schedule during the months of 3rd week of March through the 3rd week of October. Table 15 shows the irrigation schedule applied to the golf course area

Irrigation operations only occur if water surface elevation within the central stormwater pond is within the active zone, or between upper normal water level (UNWL) and the lower normal water level (LNWL). If the water surface elevation is below the LNWL, irrigation is not supplied.

Table 15: Irrigation Schedule for Golf Course

Month	Depth of Irrigation (mm/week-day)						
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Jan	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0
Mar	2	8	2	9	2	8	0
Apr	2	8	2	9	2	8	0
May	2	8	2	9	2	8	0
Jun	2	8	2	9	2	8	0
Jul	2	8	2	9	2	8	0
Aug	2	8	2	9	2	8	0
Sep	2	8	2	9	2	8	0
Oct	2	8	2	9	2	8	0
Nov	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0

4.3 Statistical Analysis of Pond Volume

Volume of ponds resulting from the simulation of the proposed drainage plan is considered highly regulated. As such, the annual maximum pond volumes (based on the simulated daily pond volumes) cannot be considered as a random time series. Therefore, a statistical analysis of the pond volumes is not performed.

5 Results

5.1 Single Event Analysis: PCSWMM Results

The results of the PCSWMM model provide the required storage volume to contain the 1:100 year, 24 hour single storm event. The volume of runoff from the design storm event is computed and compared to the active volume when the ponds are at the Upper Normal Water Level (U)NWL on the day preceding the storm event. The results of the computed volume requirements compared to the total volume provided are summarized in Table 16. The storage provided is sufficient to accommodate the 1:100 year, 24 hour single storm event for the catchment runoff to the proposed stormwater pond.

Table 16: PCSWMM Results Summary

Pond	Simulated Maximum Depth for 1:100 Storm, 24 hour (m)	Simulated Maximum Pond Volume (m^3)	Provided Maximum Pond Volume at HWL (m^3)	Overflow (m^3)
Pond 1	3.73	2,249	8,900	0
Pond 2	2.38	14,945	23,920	0
Pond 13	1.08	304	830	0
Pond 14	2.32	10,353	16,950	0
Pond 16	1.58	3,927	5,050	0
Pond 17	0.31	2,894	10,170	0
Pond 18	3.17	37,344	50,170	0
Pond 19	3.48	34,532	48,600	0
Pond CN	2.27	26,852	50,910	0
Pond NE	1.78	4,516	2,700	0
Pond SW	3.72	13,077	16,350	0

5.2 Extreme Event Analysis

Additional an extreme event analysis is performed on the ponds. The goal of this analysis is to provide the inundation extent of the two main ponds which are located at the lowest point of the development: Pond 2 for the west side of the canal and the central pond (Ponds 4 and 5) on the east side. At the start of this analysis the two main ponds are full up to the HWL. A subsequent 1:100 year, 24 hr storm event is assumed to occur and analyzed. The potential inundation extent is shown in Figure 5 and is approximately 0.4 m above HWL of Pond 2 and CN assuming sufficient freeboard on both ponds will be provided. The area shown is potential as it is based on the existing contours and proposed pond contours, no grading plan is available yet.

Legend

- Potential Inundation Extent
- Existing Pond
- Proposed Pond
- Existing Contours (1m)
- Project Site

Client:	MCINTOSH TREE FARMS INC.
Project:	SUB CATCHMENT DRAINAGE PLAN FOR FAIRWAYS AT DELACOUR
Title:	INUNDATION EXTENT FOR EXTREME FLOOD EVENT

Date:	Project No.:	Scale:	
23-03-2017	WER116-87	1:5,000	FIGURE: 5

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5.3 Continuous Simulation: Water Balance Analysis Results

The results of the continuous simulation from the Water Balance analysis are summarized in Table 17. Based on these results, the pond is sufficiently sized such that no overflow events are recorded. Figures showing the daily fluctuation of pond elevation for the entire simulation period (1960-2015) are provided in Appendix B.

Table 17: Results of Water Balance Analysis (1960 – 2015)

Pond	Simulated Maximum Depth for Continuous Simulation 1960-2015 (m)	Simulated Maximum Volume for Continuous Simulation 1960-2015 (m^3)	Provided Maximum Pond Volume at HWL (m^3)	Overflow (m^3)
Pond 1	5.54	5,574	8,900	0
Pond 2	3.40	25,322	27,950	0
Pond 13	0.64	171	830	0
Pond 14	2.31	12,102	14,660	0
Pond 16	1.56	4,210	5,050	0
Pond 17	0.61	6,228	10,170	0
Pond 18	3.47	40,752	50,170	0
Pond 19	3.55	36,143	48,600	0
Pond CN	2.97	40,580	50,910	0
Pond NE	1.78	4,272	5,440	0
Pond SW	4.21	14,269	16,350	0

5.4 Summary of Analysis

The single event analysis provides the maximum possible volume in each pond resulting from a potential extreme storm event. On the other hand, the maximum pond volume results based on the long-term continuous simulation can be considered as the most likely maximum values, but are not equivalent to the design pond volumes. A summary of the analysis result is provided in Table 18. The total storage capacity in the Ponds is 222,130 m^3. The total required storage volume is 190,000 m^3. During the detailed design process the pond system will be optimized based on the proposed grading and concept plans.

As explained in Section 4.3, a statistical analysis of annual maximum pond volumes cannot be evaluated due to the fact that the ponds in the system are inter-connected and receive/output highly regulated flows. Involvement of regulated flows destroys the stochastic nature of hydrologic variables, thus a stochastic frequency analysis is not practicable.

However, the WesthoffWB model can be used to evaluate the risk involved in design parameters, such as pond capacities, pump capacities and irrigation optimization. In this analysis, extensive statistical analysis is carried out in terms of parameters that are assigned with uncertain values. Hydrologic variables such as precipitation can also be considered as uncertain, and this can induce risk in the final estimation of pond volume. Uncertainty involved in the design parameters of other infrastructure can also contribute to the risk of estimating the maximum pond volumes. This proposed risk analysis can be considered as the right option in the absence of reliable stochastic time series representing hydrologic variables.

Table 18: Results of Pond Analysis

Pond	Governing Analysis Method	Simulated Maximum Volume Governing Method (m^3)	Provided Maximum Pond Volume at HWL (m^3)	Overflow (m^3)	Pump/ Outflow rate
Pond 1	Continuous Simulation	5,574	8,900	0	0.5 L/s
Pond 2	Continuous Simulation	25,322	27,950	0	20 L/s
Pond 13	Single Event	304	830	0	1 L/s
Pond 14	Continuous Simulation	12,102	14,660	0	0.5 L/s
Pond 16	Continuous Simulation	4,210	5,050	0	10 L/s Overland
Pond 17	Continuous Simulation	6,228	10,170	0	2 L/s Overland
Pond 18	Continuous Simulation	40,752	50,170	0	Outgoing 5 L/s to Pond Central/ Incoming 204.5 m^3/day*
Pond 19	Continuous Simulation	36,143	48,600	0	Outgoing 5 L/s to Pond Central/ Incoming 204.5 m^3/day *
Pond CN	Continuous Simulation	40,580	50,910	0	Irrigation
Pond NE	Single Event	4,516	5,440	0	2 L/s
Pond SW	Continuous Simulation	14,269	15,130	0	2 L/s
Total		**190,000**	**237,810**	**0**	

*409 m^3/day is the maximum WTP effluent rate based on 75 Imperial Gallons per person per day and 1200 residents. These rates are used in the analysis which is conservative; in reality these rates may be lower.

6 Conclusions and Recommendations

6.1 Conclusions

- The Fairways at Delacour Development area can be serviced by a comprehensive, integrated stormwater management system that embraces BMPs and LID strategies and reuse of captured runoff and treatment thereof for irrigation of the golf course
- Stormwater storage facilities are sized to handle runoff from events greater than the 1:100 year return period
- The Westhoff Water Balance (WesthoffWB) model analysis has been used to carry out sizing of stormwater storage facilities and analysis for available quantities for stormwater reuse for irrigation.
- As the ponds are integrated in the golf course and able to spill into their surrounding areas with little to no impacts, the golf course provides for a much higher level of service that the 1:100 year runoff event. A back to back 1:100 year, 24 hour design storm event would only encroach the areas surrounding the central ponds by about approximately 0.4 m.

6.2 Recommendations

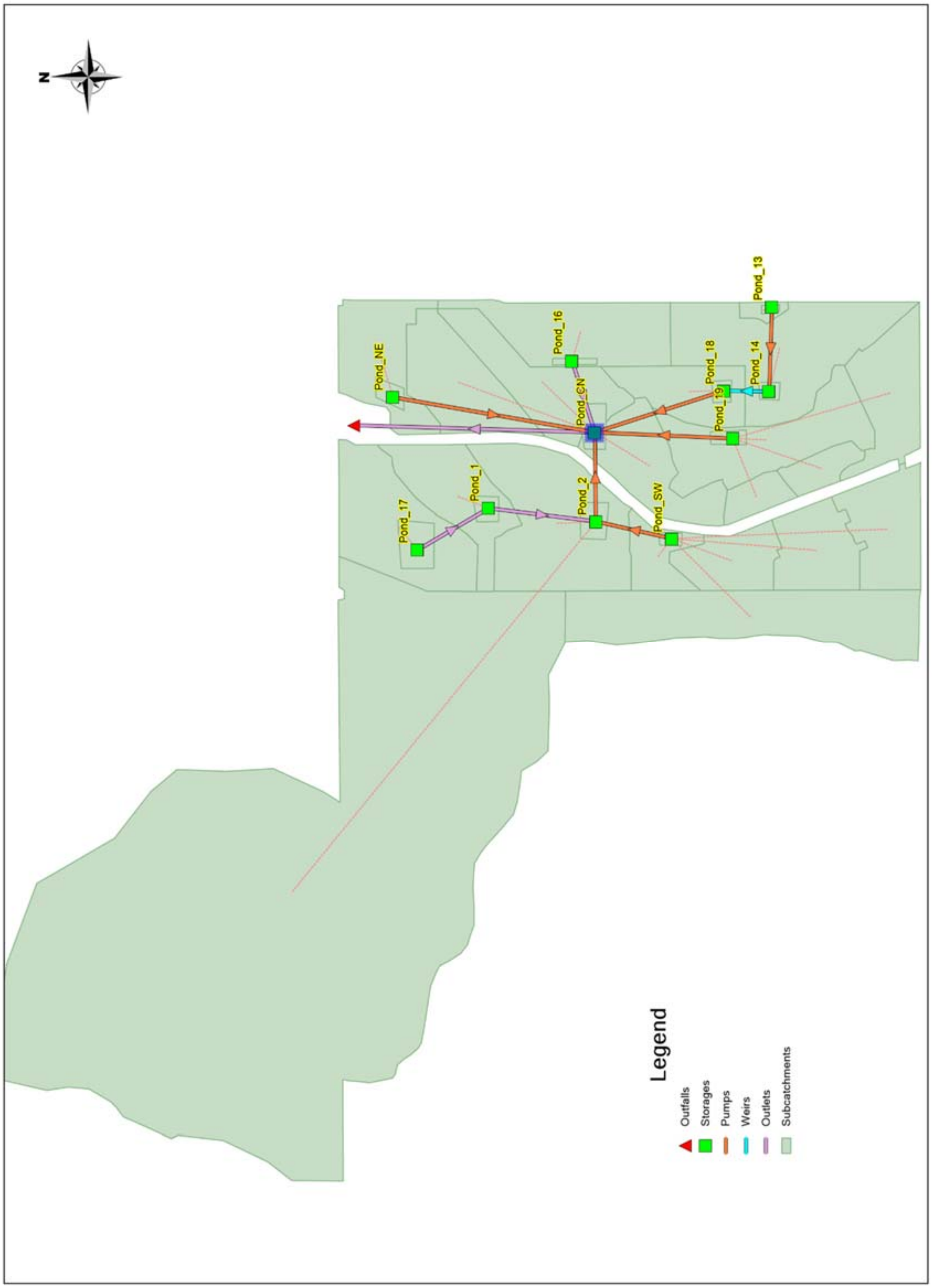
- At the detailed design stage, details are to be provided on the stormwater storage facilities, the conveyance system that includes overland drainage conveyance, gravity pipes and pump-forcemains.
- Details of the ponds, including control structures, irrigation schedules, geotechnical consideration and lining requirements and operations are to be submitted as part of the detailed design and pond report.
- A risk analysis shall be carried out at the detailed design stage to ascertain the estimation of various design values.

7 References

- Groundwater Assessment for Canal Golf Course, Sabatini Technologies Inc., 2002;
- Delacour Community Area Structure Plan, Rocky View County, 2005;
- Stormwater Management Study, Cicon Engineering Ltd., 2013;
- Fairways at Delacour Conceptual Scheme, Westcott Consulting Group Ltd., 2016.
- Rocky View County . 2013. Servicing Standards. Calgary, Alberta: Rocky View County
- Alberta Environment. 1999. Stormwater Management Guidelines. Edmonton, Ab: Municipal Program Development Branch.
- City of Calgary. 2011. Stormwater Management & Design Manual. Calgary, AB: Water Resources.

Appendix A PCSWMM Model Setup, Input and Output

Figure A1: PCSWMM Model Layout



Input File:

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;;------------------ ------------
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INFILTRATION         HORTON
FLOW_ROUTING         DYNWAVE
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START_TIME           00:00:00
REPORT_START_DATE    12/13/2016
REPORT_START_TIME    00:00:00
END_DATE             12/16/2016
END_TIME             00:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:01:00
WET_STEP             00:05:00
DRY_STEP             00:05:00
ROUTING_STEP         1
ALLOW_PONDING        NO
INERTIAL_DAMPING     PARTIAL
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         0
NORMAL_FLOW_LIMITED  BOTH
SKIP_STEADY_STATE    NO
FORCE_MAIN_EQUATION  H-W
LINK_OFFSETS         DEPTH
MIN_SLOPE            0
MAX_TRIALS           8
HEAD_TOLERANCE       0.0015
SYS_FLOW_TOL         5
LAT_FLOW_TOL         5
MINIMUM_STEP         0.5
THREADS              4

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;;Type          Parameters
;;------------- ----------
CONSTANT      0.0
DRY_ONLY      NO

[RAINGAGES]
;;              Rain      Time   Snow   Data
;;Name          Type      Intrvl Catch  Source
;;-------------- --------- ------ ------ ----------
Calgary_24h-100y INTENSITY 0:05   1.0    TIMESERIES Calgary_24h-100y

[SUBCATCHMENTS]
;;                                                Total    Pcnt.             Pcnt.    Curb     Snow
;;Name          Raingage         Outlet           Area     Imperv   Width    Slope    Length   Pack
;;-------------- ---------------- ---------------- -------- -------- -------- -------- -------- --------
CM_1            Calgary_24h-100y Pond_1           6.17     6        342.778  2        180
CM_10           Calgary_24h-100y Pond_SW          6.094508 49       338.584  2        180
CM_11           Calgary_24h-100y Pond_19          1.870749 5        311.791  2        60
CM_12           Calgary_24h-100y Pond_19          1.711165 5        342.233  2        50
CM_13           Calgary_24h-100y Pond_13          0.5      39       166.667  2        30
CM_14           Calgary_24h-100y Pond_14          12.4     46       413.333  2        0
CM_15           Calgary_24h-100y Pond_19          6.279803 43       313.99   2        200
CM_16           Calgary_24h-100y Pond_16          8.5      59       531.25   2        160
CM_17           Calgary_24h-100y Pond_17          8.74     5        485.556  2        180
CM_18           Calgary_24h-100y Pond_18          3.41     5        170.5    2        0
CM_19           Calgary_24h-100y Pond_19          7.64     5        449.412  2        170
CM_2            Calgary_24h-100y Pond_2           12.02    22       500.833  2        240
CM_3            Calgary_24h-100y Pond_CN          7.17316144373 19  398.509  2        0
CM_4            Calgary_24h-100y Pond_CN          6.05     5        432.143  2        140
CM_5            Calgary_24h-100y Pond_CN          5.32     5        354.667  2        150
CM_6            Calgary_24h-100y Pond_NE          6.39     46       236.667  2        0
CM_7            Calgary_24h-100y Pond_SW          2.6      47       216.667  2        120
CM_8            Calgary_24h-100y Pond_SW          4.145578 44       345.465  2        120
```

```
CM_9             Calgary_24h-100y Pond_SW          5.109511 44       283.862   2        180
EXT_170          Calgary_24h-100y Pond_2           142.779855 1.5    830.115   1        0
EXT_70           Calgary_24h-100y Pond_SW          14.385104 1.5     143.851   1        0
P1               Calgary_24h-100y Pond_1           0.34     100      226.667   20       0
P13              Calgary_24h-100y Pond_13          0.1081   100      108.1     20       0
P14              Calgary_24h-100y Pond_14          0.8      100      533.333   20       0
P16              Calgary_24h-100y Pond_16          0.21     100      21        20       0
P17              Calgary_24h-100y Pond_17          1.35     100      900       20       0
P18              Calgary_24h-100y Pond_18          1.53     100      1020      20       0
P19              Calgary_24h-100y Pond_19          1.44     100      960       20       0
P2               Calgary_24h-100y Pond_2           1.31     100      873.333   20       0
PNE              Calgary_24h-100y Pond_NE          0.44     100      293.333   20       0
PSW              Calgary_24h-100y Pond_SW          0.24     100      160       20       0
S1               Calgary_24h-100y Pond_CN          2.44     100      1220      20       0

[SUBAREAS]
;;Subcatchment   N-Imperv   N-Perv     S-Imperv   S-Perv     PctZero    RouteTo    PctRouted
;;-------------- ---------- ---------- ---------- ---------- ---------- ---------- ----------
CM_1             0.013      0.25       1.6        3.2        20         OUTLET
CM_10            0.013      0.25       1.6        3.2        20         OUTLET
CM_11            0.013      0.25       1.6        3.2        20         OUTLET
CM_12            0.013      0.25       1.6        3.2        20         OUTLET
CM_13            0.013      0.25       1.6        3.2        20         OUTLET
CM_14            0.013      0.25       1.6        3.2        20         OUTLET
CM_15            0.013      0.25       1.6        3.2        20         OUTLET
CM_16            0.013      0.25       1.6        3.2        20         OUTLET
CM_17            0.013      0.25       1.6        3.2        20         OUTLET
CM_18            0.013      0.25       1.6        3.2        20         OUTLET
CM_19            0.013      0.25       1.6        3.2        20         OUTLET
CM_2             0.013      0.25       1.6        3.2        20         OUTLET
CM_3             0.013      0.25       1.6        3.2        20         OUTLET
CM_4             0.013      0.25       1.6        3.2        20         OUTLET
CM_5             0.013      0.25       1.6        3.2        20         OUTLET
CM_6             0.013      0.25       1.6        3.2        20         OUTLET
CM_7             0.013      0.25       1.6        3.2        20         OUTLET
CM_8             0.013      0.25       1.6        3.2        20         OUTLET
CM_9             0.013      0.25       1.6        3.2        20         OUTLET
EXT_170          0.013      0.25       3          8          0          OUTLET
EXT_70           0.013      0.25       3          8          0          OUTLET
P1               0.013      0.25       1.6        3.2        100        OUTLET
P13              0.013      0.25       1.6        3.2        100        OUTLET
P14              0.013      0.25       1.6        3.2        100        OUTLET
P16              0.013      0.25       1.6        3.2        100        OUTLET
P17              0.013      0.25       1.6        3.2        100        OUTLET
P18              0.013      0.25       1.6        3.2        100        OUTLET
P19              0.013      0.25       1.6        3.2        100        OUTLET
P2               0.013      0.25       1.6        3.2        100        OUTLET
PNE              0.013      0.25       1.6        3.2        100        OUTLET
PSW              0.013      0.25       1.6        3.2        100        OUTLET
S1               0.013      0.25       1.6        3.2        100        OUTLET

[INFILTRATION]
;;Subcatchment   MaxRate    MinRate    Decay      DryTime    MaxInfil
;;-------------- ---------- ---------- ---------- ---------- ----------
CM_1             75         7.5        4.14       7          0
CM_10            75         7.5        4.14       7          0
CM_11            75         7.5        4.14       7          0
CM_12            75         7.5        4.14       7          0
CM_13            75         7.5        4.14       7          0
CM_14            75         7.5        4.14       7          0
CM_15            75         7.5        4.14       7          0
CM_16            75         7.5        4.14       7          0
CM_17            75         7.5        4.14       7          0
CM_18            75         7.5        4.14       7          0
CM_19            75         7.5        4.14       7          0
CM_2             75         7.5        4.14       7          0
CM_3             75         7.5        4.14       7          0
CM_4             75         7.5        4.14       7          0
CM_5             75         7.5        4.14       7          0
CM_6             75         7.5        4.14       7          0
CM_7             75         7.5        4.14       7          0
CM_8             75         7.5        4.14       7          0
CM_9             75         7.5        4.14       7          0
EXT_170          75         7.5        4.14       7          0
EXT_70           75         7.5        4.14       7          0
P1               75         7.5        4.14       7          0
```



```
P13              75         7.5        4.14       5          0
P14              75         7.5        4.14       5          0
P16              75         7.5        4.14       5          0
P17              75         7.5        4.14       5          0
P18              75         7.5        4.14       5          0
P19              75         7.5        4.14       5          0
P2               75         7.5        4.14       7          0
PNE              75         7.5        4.14       5          0
PSW              75         7.5        4.14       5          0
S1               75         7.5        4.14       5          0

[OUTFALLS]
;;               Invert     Outfall      Stage/Table      Tide
;;Name           Elev.      Type         Time Series      Gate Route To
;;-------------- ---------- ------------ ---------------- ---- ----------------
Outfall1         5          FREE                          NO

[STORAGE]
;;               Invert   Max.     Init.    Storage    Curve                      Ponded   Evap.
;;Name           Elev.    Depth    Depth    Curve      Params                     Area     Frac.
Infiltration parameters
;;-------------- -------- -------- -------- ---------- -------- -------- -------- -------- -------- ----------
-------------
Pond_1           10       7        2        TABULAR    Pond_1                     0        0
Pond_13          10       2        0        TABULAR    Pond_13                    0        0
Pond_14          8        3        1        TABULAR    Pond_14                    0        0
Pond_16          8        2        0        TABULAR    Pond_16                    0        0
Pond_17          16       2        0        TABULAR    Pond_17                    0        0
Pond_18          7        4        3        TABULAR    Pond_18                    0        0
Pond_19          7        4        3        TABULAR    Pond_19                    0        0
Pond_2           7        3.6      1        TABULAR    Pond_2                     0        0
Pond_CN          5        3.5      1        TABULAR    Pond_CN                    0        0
Pond_NE          5        2        1        TABULAR    Pond_NE                    0        0
Pond_SW          7        4        1        TABULAR    Pond_SW                    0        0

[PUMPS]
;;               Inlet            Outlet           Pump             Init.  Startup  Shutoff
;;Name           Node             Node             Curve            Status Depth    Depth
;;-------------- ---------------- ---------------- ---------------- ------ -------- --------
P_13             Pond_13          Pond_14          Pond_13_18       ON     0        0
P_18             Pond_18          Pond_CN          Pond_14_CN       ON     0        0
P_36             Pond_NE          Pond_CN          Pond_NE_CN       ON     0        0
P_SW             Pond_SW          Pond_2           Pond_SW_CN       ON     0        0
P19_CE           Pond_19          Pond_CN          Pond_19_CN       ON     0        0
P2_CE            Pond_2           Pond_CN          Pond_2_CN        ON     0        0

[WEIRS]
;;               Inlet            Outlet           Weir         Crest      Disch.     Flap End      End
;;Name           Node             Node             Type         Height     Coeff.     Gate Con.     Coeff.
Surcharge  RoadWidth  RoadSurf
;;-------------- ---------------- ---------------- ------------ ---------- ---------- ---- -------- ----------
---------- ---------- ----------
W14_18           Pond_14          Pond_18          TRANSVERSE   2.75       1.75       YES  0        0
YES

[OUTLETS]
;;               Inlet            Outlet           Outflow    Outlet           Qcoeff/
Flap
;;Name           Node             Node             Height     Type             QTable           Qexpon
Gate
;;-------------- ---------------- ---------------- ---------- ---------------- ---------------- ---------- ---
-
C1_2             Pond_1           Pond_2           2          TABULAR/DEPTH    P_1                         YES
C17_1            Pond_17          Pond_1           0          TABULAR/DEPTH    P_17                        YES
P_16             Pond_16          Pond_CN          0          TABULAR/DEPTH    P_16                        YES
Spiilway         Pond_CN          Outfall1         3.4        TABULAR/DEPTH    Spill                       YES

[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3      Geom4      Barrels
;;-------------- ------------ ---------------- ---------- ---------- ---------- ----------
W14_18           RECT_OPEN    0.25             70         0          0

[INFLOWS]
;;                                                 Param    Units    Scale    Baseline Baseline
;;Node           Parameter        Time Series      Type     Factor   Factor   Value    Pattern
;;-------------- ---------------- ---------------- -------- -------- -------- -------- --------
```

```
Pond_18          FLOW        ""           FLOW     1.0      1        0.0024
Pond_19          FLOW        ""           FLOW     1.0      1        0.0024

[CURVES]
;;Name           Type       X-Value    Y-Value
;;-------------- ---------- ---------- ----------
Pond_13_18       Pump4      0          0
Pond_13_18                  2          0.001

Pond_14_CN       Pump4      0          0
Pond_14_CN                  2.5        0
Pond_14_CN                  3.7        0
Pond_14_CN                  4          0.005

Pond_19_CN       Pump4      0          0
Pond_19_CN                  2          0
Pond_19_CN                  3.7        0
Pond_19_CN                  4          0.005

Pond_2_CN        Pump4      0          0
Pond_2_CN                   1          0
Pond_2_CN                   3.3        0.02

Pond_NE_CN       Pump4      0          0
Pond_NE_CN                  1          0
Pond_NE_CN                  2          0.03

Pond_SW_CN       Pump4      0          0
Pond_SW_CN                  1          0
Pond_SW_CN                  4          0.002

P_1              Rating     0          0
P_1                         4.5        0.001

P_16             Rating     0          0
P_16                        2          0.03

P_17             Rating     0          0
P_17                        1.75       0.005

P_SE             Rating     0          0
P_SE                        1.2        0.05

Spill            Rating     0          0
Spill                       0.1        5

Pond_1           Storage    0          38
Pond_1                      1          248
Pond_1                      2          592
Pond_1                      3          1025
Pond_1                      4          1530
Pond_1                      5          2099
Pond_1                      6          2724
Pond_1                      7          3407

;Dry Pond
Pond_13          Storage    0          69
Pond_13                     1          462
Pond_13                     2          1046

Pond_14          Storage    0          2605
Pond_14                     1          4083
Pond_14                     2          5960
Pond_14                     3          8038

;Dry Pond
Pond_16          Storage    0          290
Pond_16                     1          3049
Pond_16                     2          5966

;Dry pond
Pond_17          Storage    0          9098
Pond_17                     1          11233
Pond_17                     2          13531

;Wastewater Pond
```

```
Pond_18          Storage    0          8196
Pond_18                     1          10341
Pond_18                     2          12666
Pond_18                     3          15166
Pond_18                     4          17445

;Wastewater Pond
Pond_19          Storage    0          4144
Pond_19                     1          7262
Pond_19                     2          10693
Pond_19                     3          14361
Pond_19                     4          18194

Pond_2           Storage    0          4078
Pond_2                      1          5818
Pond_2                      2.7        9382
Pond_2                      3.3        10781
Pond_2                      3.6        16127

;Pond_4_5
Pond_CN          Storage    0          8988
Pond_CN                     1          10753
Pond_CN                     2          14938
Pond_CN                     3          19504
Pond_CN                     3.5        24401

;Pond_3_6
Pond_NE          Storage    0          1488
Pond_NE                     1          2521
Pond_NE                     2          4355

;Pond 11_12_15
Pond_SE          Storage    0          416
Pond_SE                     1          3260
Pond_SE                     2          7100
Pond_SE                     2.5        11015

;Pond_7_8_9_10
Pond_SW          Storage    0          835
Pond_SW                     1          1279
Pond_SW                     2          1799
Pond_SW                     3          2380
Pond_SW                     3.1        5742
Pond_SW                     3.5        7658
Pond_SW                     4          9589

[TIMESERIES]
;;Name           Date       Time       Value
;;-------------- ---------- ---------- ----------
;Calgary_24h-100y design storm, rain interval = 5 minutes, rain units = mm/hr.
Calgary_24h-100y            0:00       0
Calgary_24h-100y            0:05       1.094
Calgary_24h-100y            0:10       1.103
Calgary_24h-100y            0:15       1.113
Calgary_24h-100y            0:20       1.122
Calgary_24h-100y            0:25       1.132
Calgary_24h-100y            0:30       1.143
Calgary_24h-100y            0:35       1.153
Calgary_24h-100y            0:40       1.163
Calgary_24h-100y            0:45       1.174
Calgary_24h-100y            0:50       1.185
Calgary_24h-100y            0:55       1.197
Calgary_24h-100y            1:00       1.208
Calgary_24h-100y            1:05       1.22
Calgary_24h-100y            1:10       1.232
Calgary_24h-100y            1:15       1.245
Calgary_24h-100y            1:20       1.257
Calgary_24h-100y            1:25       1.27
Calgary_24h-100y            1:30       1.284
Calgary_24h-100y            1:35       1.297
Calgary_24h-100y            1:40       1.311
Calgary_24h-100y            1:45       1.326
Calgary_24h-100y            1:50       1.341
Calgary_24h-100y            1:55       1.356
Calgary_24h-100y            2:00       1.372
Calgary_24h-100y            2:05       1.388
```

Calgary_24h-100y	2:10	1.404
Calgary_24h-100y	2:15	1.421
Calgary_24h-100y	2:20	1.439
Calgary_24h-100y	2:25	1.457
Calgary_24h-100y	2:30	1.476
Calgary_24h-100y	2:35	1.495
Calgary_24h-100y	2:40	1.515
Calgary_24h-100y	2:45	1.535
Calgary_24h-100y	2:50	1.556
Calgary_24h-100y	2:55	1.578
Calgary_24h-100y	3:00	1.601
Calgary_24h-100y	3:05	1.624
Calgary_24h-100y	3:10	1.648
Calgary_24h-100y	3:15	1.674
Calgary_24h-100y	3:20	1.7
Calgary_24h-100y	3:25	1.727
Calgary_24h-100y	3:30	1.755
Calgary_24h-100y	3:35	1.784
Calgary_24h-100y	3:40	1.815
Calgary_24h-100y	3:45	1.846
Calgary_24h-100y	3:50	1.88
Calgary_24h-100y	3:55	1.914
Calgary_24h-100y	4:00	1.95
Calgary_24h-100y	4:05	1.988
Calgary_24h-100y	4:10	2.028
Calgary_24h-100y	4:15	2.07
Calgary_24h-100y	4:20	2.113
Calgary_24h-100y	4:25	2.159
Calgary_24h-100y	4:30	2.208
Calgary_24h-100y	4:35	2.259
Calgary_24h-100y	4:40	2.313
Calgary_24h-100y	4:45	2.371
Calgary_24h-100y	4:50	2.432
Calgary_24h-100y	4:55	2.497
Calgary_24h-100y	5:00	2.566
Calgary_24h-100y	5:05	2.64
Calgary_24h-100y	5:10	2.719
Calgary_24h-100y	5:15	2.805
Calgary_24h-100y	5:20	2.897
Calgary_24h-100y	5:25	2.997
Calgary_24h-100y	5:30	3.105
Calgary_24h-100y	5:35	3.224
Calgary_24h-100y	5:40	3.354
Calgary_24h-100y	5:45	3.497
Calgary_24h-100y	5:50	3.656
Calgary_24h-100y	5:55	3.833
Calgary_24h-100y	6:00	4.033
Calgary_24h-100y	6:05	4.259
Calgary_24h-100y	6:10	4.519
Calgary_24h-100y	6:15	4.821
Calgary_24h-100y	6:20	5.176
Calgary_24h-100y	6:25	5.601
Calgary_24h-100y	6:30	6.12
Calgary_24h-100y	6:35	6.773
Calgary_24h-100y	6:40	7.624
Calgary_24h-100y	6:45	8.785
Calgary_24h-100y	6:50	10.488
Calgary_24h-100y	6:55	13.283
Calgary_24h-100y	7:00	18.961
Calgary_24h-100y	7:05	40.516
Calgary_24h-100y	7:10	168.138
Calgary_24h-100y	7:15	54.372
Calgary_24h-100y	7:20	31.748
Calgary_24h-100y	7:25	23.236
Calgary_24h-100y	7:30	18.66
Calgary_24h-100y	7:35	15.763
Calgary_24h-100y	7:40	13.746
Calgary_24h-100y	7:45	12.251
Calgary_24h-100y	7:50	11.093
Calgary_24h-100y	7:55	10.166
Calgary_24h-100y	8:00	9.405
Calgary_24h-100y	8:05	8.768
Calgary_24h-100y	8:10	8.225
Calgary_24h-100y	8:15	7.756
Calgary_24h-100y	8:20	7.346
Calgary_24h-100y	8:25	6.985

```
Calgary_24h-100y            8:30        6.664
Calgary_24h-100y            8:35        6.376
Calgary_24h-100y            8:40        6.116
Calgary_24h-100y            8:45        5.88
Calgary_24h-100y            8:50        5.665
Calgary_24h-100y            8:55        5.468
Calgary_24h-100y            9:00        5.287
Calgary_24h-100y            9:05        5.119
Calgary_24h-100y            9:10        4.964
Calgary_24h-100y            9:15        4.819
Calgary_24h-100y            9:20        4.684
Calgary_24h-100y            9:25        4.558
Calgary_24h-100y            9:30        4.44
Calgary_24h-100y            9:35        4.329
Calgary_24h-100y            9:40        4.224
Calgary_24h-100y            9:45        4.125
Calgary_24h-100y            9:50        4.032
Calgary_24h-100y            9:55        3.943
Calgary_24h-100y            10:00       3.859
Calgary_24h-100y            10:05       3.78
Calgary_24h-100y            10:10       3.704
Calgary_24h-100y            10:15       3.631
Calgary_24h-100y            10:20       3.562
Calgary_24h-100y            10:25       3.496
Calgary_24h-100y            10:30       3.433
Calgary_24h-100y            10:35       3.373
Calgary_24h-100y            10:40       3.315
Calgary_24h-100y            10:45       3.259
Calgary_24h-100y            10:50       3.206
Calgary_24h-100y            10:55       3.154
Calgary_24h-100y            11:00       3.105
Calgary_24h-100y            11:05       3.057
Calgary_24h-100y            11:10       3.011
Calgary_24h-100y            11:15       2.967
Calgary_24h-100y            11:20       2.924
Calgary_24h-100y            11:25       2.883
Calgary_24h-100y            11:30       2.843
Calgary_24h-100y            11:35       2.805
Calgary_24h-100y            11:40       2.767
Calgary_24h-100y            11:45       2.731
Calgary_24h-100y            11:50       2.696
Calgary_24h-100y            11:55       2.662
Calgary_24h-100y            12:00       2.629
Calgary_24h-100y            12:05       2.597
Calgary_24h-100y            12:10       2.566
Calgary_24h-100y            12:15       2.536
Calgary_24h-100y            12:20       2.506
Calgary_24h-100y            12:25       2.478
Calgary_24h-100y            12:30       2.45
Calgary_24h-100y            12:35       2.423
Calgary_24h-100y            12:40       2.396
Calgary_24h-100y            12:45       2.371
Calgary_24h-100y            12:50       2.346
Calgary_24h-100y            12:55       2.321
Calgary_24h-100y            13:00       2.297
Calgary_24h-100y            13:05       2.274
Calgary_24h-100y            13:10       2.252
Calgary_24h-100y            13:15       2.229
Calgary_24h-100y            13:20       2.208
Calgary_24h-100y            13:25       2.187
Calgary_24h-100y            13:30       2.166
Calgary_24h-100y            13:35       2.146
Calgary_24h-100y            13:40       2.126
Calgary_24h-100y            13:45       2.107
Calgary_24h-100y            13:50       2.088
Calgary_24h-100y            13:55       2.069
Calgary_24h-100y            14:00       2.051
Calgary_24h-100y            14:05       2.034
Calgary_24h-100y            14:10       2.016
Calgary_24h-100y            14:15       1.999
Calgary_24h-100y            14:20       1.983
Calgary_24h-100y            14:25       1.966
Calgary_24h-100y            14:30       1.95
Calgary_24h-100y            14:35       1.935
Calgary_24h-100y            14:40       1.919
Calgary_24h-100y            14:45       1.904
```

Calgary_24h-100y	14:50	1.889
Calgary_24h-100y	14:55	1.875
Calgary_24h-100y	15:00	1.86
Calgary_24h-100y	15:05	1.846
Calgary_24h-100y	15:10	1.833
Calgary_24h-100y	15:15	1.819
Calgary_24h-100y	15:20	1.806
Calgary_24h-100y	15:25	1.793
Calgary_24h-100y	15:30	1.78
Calgary_24h-100y	15:35	1.767
Calgary_24h-100y	15:40	1.755
Calgary_24h-100y	15:45	1.743
Calgary_24h-100y	15:50	1.731
Calgary_24h-100y	15:55	1.719
Calgary_24h-100y	16:00	1.707
Calgary_24h-100y	16:05	1.696
Calgary_24h-100y	16:10	1.685
Calgary_24h-100y	16:15	1.673
Calgary_24h-100y	16:20	1.663
Calgary_24h-100y	16:25	1.652
Calgary_24h-100y	16:30	1.641
Calgary_24h-100y	16:35	1.631
Calgary_24h-100y	16:40	1.621
Calgary_24h-100y	16:45	1.611
Calgary_24h-100y	16:50	1.601
Calgary_24h-100y	16:55	1.591
Calgary_24h-100y	17:00	1.581
Calgary_24h-100y	17:05	1.572
Calgary_24h-100y	17:10	1.562
Calgary_24h-100y	17:15	1.553
Calgary_24h-100y	17:20	1.544
Calgary_24h-100y	17:25	1.535
Calgary_24h-100y	17:30	1.526
Calgary_24h-100y	17:35	1.517
Calgary_24h-100y	17:40	1.509
Calgary_24h-100y	17:45	1.5
Calgary_24h-100y	17:50	1.492
Calgary_24h-100y	17:55	1.484
Calgary_24h-100y	18:00	1.476
Calgary_24h-100y	18:05	1.467
Calgary_24h-100y	18:10	1.46
Calgary_24h-100y	18:15	1.452
Calgary_24h-100y	18:20	1.444
Calgary_24h-100y	18:25	1.436
Calgary_24h-100y	18:30	1.429
Calgary_24h-100y	18:35	1.421
Calgary_24h-100y	18:40	1.414
Calgary_24h-100y	18:45	1.407
Calgary_24h-100y	18:50	1.399
Calgary_24h-100y	18:55	1.392
Calgary_24h-100y	19:00	1.385
Calgary_24h-100y	19:05	1.378
Calgary_24h-100y	19:10	1.372
Calgary_24h-100y	19:15	1.365
Calgary_24h-100y	19:20	1.358
Calgary_24h-100y	19:25	1.352
Calgary_24h-100y	19:30	1.345
Calgary_24h-100y	19:35	1.339
Calgary_24h-100y	19:40	1.332
Calgary_24h-100y	19:45	1.326
Calgary_24h-100y	19:50	1.32
Calgary_24h-100y	19:55	1.313
Calgary_24h-100y	20:00	1.307
Calgary_24h-100y	20:05	1.301
Calgary_24h-100y	20:10	1.295
Calgary_24h-100y	20:15	1.289
Calgary_24h-100y	20:20	1.284
Calgary_24h-100y	20:25	1.278
Calgary_24h-100y	20:30	1.272
Calgary_24h-100y	20:35	1.266
Calgary_24h-100y	20:40	1.261
Calgary_24h-100y	20:45	1.255
Calgary_24h-100y	20:50	1.25
Calgary_24h-100y	20:55	1.244
Calgary_24h-100y	21:00	1.239
Calgary_24h-100y	21:05	1.234

```
Calgary_24h-100y            21:10      1.229
Calgary_24h-100y            21:15      1.223
Calgary_24h-100y            21:20      1.218
Calgary_24h-100y            21:25      1.213
Calgary_24h-100y            21:30      1.208
Calgary_24h-100y            21:35      1.203
Calgary_24h-100y            21:40      1.198
Calgary_24h-100y            21:45      1.193
Calgary_24h-100y            21:50      1.188
Calgary_24h-100y            21:55      1.184
Calgary_24h-100y            22:00      1.179
Calgary_24h-100y            22:05      1.174
Calgary_24h-100y            22:10      1.17
Calgary_24h-100y            22:15      1.165
Calgary_24h-100y            22:20      1.16
Calgary_24h-100y            22:25      1.156
Calgary_24h-100y            22:30      1.151
Calgary_24h-100y            22:35      1.147
Calgary_24h-100y            22:40      1.143
Calgary_24h-100y            22:45      1.138
Calgary_24h-100y            22:50      1.134
Calgary_24h-100y            22:55      1.13
Calgary_24h-100y            23:00      1.125
Calgary_24h-100y            23:05      1.121
Calgary_24h-100y            23:10      1.117
Calgary_24h-100y            23:15      1.113
Calgary_24h-100y            23:20      1.109
Calgary_24h-100y            23:25      1.105
Calgary_24h-100y            23:30      1.101
Calgary_24h-100y            23:35      1.097
Calgary_24h-100y            23:40      1.093
Calgary_24h-100y            23:45      1.089
Calgary_24h-100y            23:50      1.085
Calgary_24h-100y            23:55      1.081
Calgary_24h-100y            24:00      1.077

[REPORT]
INPUT      YES
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL
```

- Output File:

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.011)
--------------------------------------------------------------

EX170 to Pond2


*************
Element Count
*************
Number of rain gages ...... 1
Number of subcatchments ... 32
Number of nodes ........... 12
Number of links ........... 11
Number of pollutants ...... 0
Number of land uses ....... 0


****************
Raingage Summary
****************
                                                Data       Recording
Name                 Data Source                Type       Interval 
-----------------------------------------------------------------------
Calgary_24h-100y     Calgary_24h-100y           INTENSITY    5 min.


********************
Subcatchment Summary
********************
Name                       Area     Width   %Imperv    %Slope Rain Gage            Outlet
--------------------------------------------------------------------------------------------------------------
CM_1                       6.17    342.78      6.00    2.0000 Calgary_24h-100y     Pond_1
CM_10                      6.09    338.58     49.00    2.0000 Calgary_24h-100y     Pond_SW
CM_11                      1.87    311.79      5.00    2.0000 Calgary_24h-100y     Pond_19
CM_12                      1.71    342.23      5.00    2.0000 Calgary_24h-100y     Pond_19
CM_13                      0.50    166.67     39.00    2.0000 Calgary_24h-100y     Pond_13
CM_14                     12.40    413.33     46.00    2.0000 Calgary_24h-100y     Pond_14
CM_15                      6.28    313.99     43.00    2.0000 Calgary_24h-100y     Pond_19
CM_16                      8.50    531.25     59.00    2.0000 Calgary_24h-100y     Pond_16
CM_17                      8.74    485.56      5.00    2.0000 Calgary_24h-100y     Pond_17
CM_18                      3.41    170.50      5.00    2.0000 Calgary_24h-100y     Pond_18
CM_19                      7.64    449.41      5.00    2.0000 Calgary_24h-100y     Pond_19
CM_2                      12.02    500.83     22.00    2.0000 Calgary_24h-100y     Pond_2
CM_3                       7.17    398.51     19.00    2.0000 Calgary_24h-100y     Pond_CN
CM_4                       6.05    432.14      5.00    2.0000 Calgary_24h-100y     Pond_CN
CM_5                       5.32    354.67      5.00    2.0000 Calgary_24h-100y     Pond_CN
CM_6                       6.39    236.67     46.00    2.0000 Calgary_24h-100y     Pond_NE
CM_7                       2.60    216.67     47.00    2.0000 Calgary_24h-100y     Pond_SW
CM_8                       4.15    345.47     44.00    2.0000 Calgary_24h-100y     Pond_SW
CM_9                       5.11    283.86     44.00    2.0000 Calgary_24h-100y     Pond_SW
EXT_170                  142.78    830.12      1.50    1.0000 Calgary_24h-100y     Pond_2
EXT_70                    14.39    143.85      1.50    1.0000 Calgary_24h-100y     Pond_SW
P1                         0.34    226.67    100.00   20.0000 Calgary_24h-100y     Pond_1
P13                        0.11    108.10    100.00   20.0000 Calgary_24h-100y     Pond_13
P14                        0.80    533.33    100.00   20.0000 Calgary_24h-100y     Pond_14
P16                        0.21     21.00    100.00   20.0000 Calgary_24h-100y     Pond_16
P17                        1.35    900.00    100.00   20.0000 Calgary_24h-100y     Pond_17
P18                        1.53   1020.00    100.00   20.0000 Calgary_24h-100y     Pond_18
P19                        1.44    960.00    100.00   20.0000 Calgary_24h-100y     Pond_19
P2                         1.31    873.33    100.00   20.0000 Calgary_24h-100y     Pond_2
PNE                        0.44    293.33    100.00   20.0000 Calgary_24h-100y     Pond_NE
PSW                        0.24    160.00    100.00   20.0000 Calgary_24h-100y     Pond_SW
S1                         2.44   1220.00    100.00   20.0000 Calgary_24h-100y     Pond_CN


************
Node Summary
************
                                           Invert      Max.    Ponded    External
Name                 Type                   Elev.     Depth      Area    Inflow  
-------------------------------------------------------------------------------
```

```
Outfall1            OUTFALL              5.00      0.00       0.0
Pond_1              STORAGE             10.00      7.00       0.0
Pond_13             STORAGE             10.00      2.00       0.0
Pond_14             STORAGE              8.00      3.00       0.0
Pond_16             STORAGE              8.00      2.00       0.0
Pond_17             STORAGE             16.00      2.00       0.0
Pond_18             STORAGE              7.00      4.00       0.0      Yes
Pond_19             STORAGE              7.00      4.00       0.0      Yes
Pond_2              STORAGE              7.00      3.60       0.0
Pond_CN             STORAGE              5.00      3.50       0.0
Pond_NE             STORAGE              5.00      2.00       0.0
Pond_SW             STORAGE              7.00      4.00       0.0


************
Link Summary
************
Name             From Node        To Node          Type            Length    %Slope Roughness
---------------------------------------------------------------------------------------------
P_13             Pond_13          Pond_14          TYPE4 PUMP
P_18             Pond_18          Pond_CN          TYPE4 PUMP
P_36             Pond_NE          Pond_CN          TYPE4 PUMP
P_SW             Pond_SW          Pond_2           TYPE4 PUMP
P19_CE           Pond_19          Pond_CN          TYPE4 PUMP
P2_CE            Pond_2           Pond_CN          TYPE4 PUMP
W14_18           Pond_14          Pond_18          WEIR
C1_2             Pond_1           Pond_2           OUTLET
C17_1            Pond_17          Pond_1           OUTLET
P_16             Pond_16          Pond_CN          OUTLET
Spiilway         Pond_CN          Outfall1         OUTLET


*********************
Cross Section Summary
*********************
                                       Full     Full     Hyd.     Max.   No. of     Full
Conduit          Shape                Depth     Area     Rad.    Width  Barrels     Flow
---------------------------------------------------------------------------------------



*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... HORTON
Flow Routing Method ...... DYNWAVE
Starting Date ............ 12/13/2016 00:00:00
Ending Date .............. 12/16/2016 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:01:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 00:05:00
Routing Time Step ........ 1.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 1
Head Tolerance ........... 0.001500 m


**************************        Volume         Depth
Runoff Quantity Continuity     hectare-m            mm
```

```
**************************        ---------       -------
Total Precipitation ......           25.062        89.667
Evaporation Loss .........            0.000         0.000
Infiltration Loss ........           19.361        69.271
Surface Runoff ...........            5.682        20.329
Final Storage ............            0.047         0.167
Continuity Error (%) .....           -0.111


**************************          Volume        Volume
Flow Routing Continuity           hectare-m      10^6 ltr
**************************        ---------     ---------
Dry Weather Inflow .......            0.000         0.000
Wet Weather Inflow .......            5.682        56.819
Groundwater Inflow .......            0.000         0.000
RDII Inflow ..............            0.000         0.000
External Inflow ..........            0.124         1.244
External Outflow .........            0.000         0.000
Flooding Loss ............            0.000         0.000
Evaporation Loss .........            0.000         0.000
Exfiltration Loss ........            0.000         0.000
Initial Stored Volume ....            8.367        83.674
Final Stored Volume ......           14.173       141.730
Continuity Error (%) .....            0.005


***************************
Time-Step Critical Elements
***************************
None


********************************
Highest Flow Instability Indexes
********************************
All links are stable.


*************************
Routing Time Step Summary
*************************
Minimum Time Step           :     0.50 sec
Average Time Step           :     1.00 sec
Maximum Time Step           :     1.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     2.00
Percent Not Converging      :     0.00


***************************
Subcatchment Runoff Summary
***************************
```

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
CM_1	89.67	0.00	0.00	69.10	20.59	1.27	0.30	0.230
CM_10	89.67	0.00	0.00	36.38	53.02	3.23	1.39	0.591
CM_11	89.67	0.00	0.00	66.57	23.30	0.44	0.15	0.260
CM_12	89.67	0.00	0.00	66.21	23.71	0.41	0.16	0.264
CM_13	89.67	0.00	0.00	41.70	47.94	0.24	0.14	0.535
CM_14	89.67	0.00	0.00	39.60	49.79	6.17	2.36	0.555
CM_15	89.67	0.00	0.00	41.06	48.37	3.04	1.27	0.539
CM_16	89.67	0.00	0.00	28.87	60.47	5.14	2.29	0.674
CM_17	89.67	0.00	0.00	69.87	19.83	1.73	0.38	0.221
CM_18	89.67	0.00	0.00	70.29	19.40	0.66	0.14	0.216
CM_19	89.67	0.00	0.00	69.65	20.05	1.53	0.34	0.224
CM_2	89.67	0.00	0.00	57.66	31.89	3.83	1.38	0.356
CM_3	89.67	0.00	0.00	59.07	30.51	2.19	0.77	0.340
CM_4	89.67	0.00	0.00	68.95	20.78	1.26	0.30	0.232
CM_5	89.67	0.00	0.00	69.19	20.53	1.09	0.25	0.229
CM_6	89.67	0.00	0.00	39.38	50.02	3.20	1.26	0.558
CM_7	89.67	0.00	0.00	37.28	52.14	1.36	0.62	0.581
CM_8	89.67	0.00	0.00	39.46	49.97	2.07	0.94	0.557

CM_9	89.67	0.00	0.00	40.11	49.32	2.52	1.07	0.550
EXT_170	89.67	0.00	0.00	85.76	3.88	5.54	1.09	0.043
EXT_70	89.67	0.00	0.00	84.41	5.23	0.75	0.12	0.058
P1	89.67	0.00	0.00	0.00	89.68	0.30	0.16	1.000
P13	89.67	0.00	0.00	0.00	89.68	0.10	0.05	1.000
P14	89.67	0.00	0.00	0.00	89.68	0.72	0.37	1.000
P16	89.67	0.00	0.00	0.00	89.94	0.19	0.10	1.003
P17	89.67	0.00	0.00	0.00	89.68	1.21	0.63	1.000
P18	89.67	0.00	0.00	0.00	89.68	1.37	0.71	1.000
P19	89.67	0.00	0.00	0.00	89.68	1.29	0.67	1.000
P2	89.67	0.00	0.00	0.00	89.68	1.17	0.61	1.000
PNE	89.67	0.00	0.00	0.00	89.68	0.39	0.21	1.000
PSW	89.67	0.00	0.00	0.00	89.68	0.22	0.11	1.000
S1	89.67	0.00	0.00	0.00	89.69	2.19	1.14	1.000

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min	Reported Max Depth Meters
Outfall1	OUTFALL	0.00	0.00	5.00	0 00:00	0.00
Pond_1	STORAGE	3.49	3.73	13.73	3 00:00	3.73
Pond_13	STORAGE	0.91	1.08	11.08	1 00:07	1.08
Pond_14	STORAGE	2.14	2.32	10.32	3 00:00	2.32
Pond_16	STORAGE	1.14	1.58	9.58	0 16:49	1.58
Pond_17	STORAGE	0.27	0.31	16.31	1 00:13	0.31
Pond_18	STORAGE	3.14	3.17	10.17	3 00:00	3.17
Pond_19	STORAGE	3.41	3.48	10.48	3 00:00	3.48
Pond_2	STORAGE	2.15	2.38	9.38	1 00:10	2.38
Pond_CN	STORAGE	1.87	2.27	7.27	3 00:00	2.27
Pond_NE	STORAGE	1.42	1.78	6.78	0 12:38	1.78
Pond_SW	STORAGE	3.58	3.89	10.89	1 01:02	3.89

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr	Flow Balance Error Percent
Outfall1	OUTFALL	0.000	0.000	0 00:00	0	0	0.000 ltr
Pond_1	STORAGE	0.458	0.458	0 07:15	1.58	2.33	0.008
Pond_13	STORAGE	0.190	0.190	0 07:15	0.337	0.337	0.007
Pond_14	STORAGE	2.737	2.737	0 07:15	6.89	10.4	0.008
Pond_16	STORAGE	2.390	2.390	0 07:15	5.33	5.33	0.002
Pond_17	STORAGE	1.013	1.013	0 07:15	2.94	2.94	0.010
Pond_18	STORAGE	0.860	0.860	0 07:15	2.66	37.3	0.001
Pond_19	STORAGE	2.591	2.591	0 07:15	7.32	34.5	0.002
Pond_2	STORAGE	3.075	3.076	0 07:15	10.5	16	0.006
Pond_CN	STORAGE	2.467	2.491	0 07:15	6.73	26.9	0.007
Pond_NE	STORAGE	1.461	1.461	0 07:15	3.59	5.6	0.001
Pond_SW	STORAGE	4.260	4.260	0 07:15	10.1	11.2	0.010

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

```
**********************
Storage Volume Summary
**********************
```

Storage Unit	Average Volume 1000 m3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 m3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CMS
Pond_1	1.998	20	0	0	2.249	23	3 00:00	0.000
Pond_13	0.239	23	0	0	0.304	30	1 00:07	0.001
Pond_14	9.384	61	0	0	10.353	67	3 00:00	0.000
Pond_16	2.351	38	0	0	3.927	64	0 16:49	0.024
Pond_17	2.495	11	0	0	2.894	13	1 00:13	0.001
Pond_18	36.775	72	0	0	37.344	73	3 00:00	0.000
Pond_19	33.385	77	0	0	34.532	79	3 00:00	0.000
Pond_2	13.206	47	0	0	14.945	53	1 00:10	0.012
Pond_CN	21.080	41	0	0	26.852	53	3 00:00	0.000
Pond_NE	3.264	60	0	0	4.516	83	0 12:38	0.023
Pond_SW	9.690	80	0	0	11.074	92	1 01:02	0.002

```
***********************
Outfall Loading Summary
***********************
```

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
Outfall1	0.00	0.000	0.000	0.000
System	0.00	0.000	0.000	0.000

```
********************
Link Flow Summary
********************
```

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
P_13	PUMP	0.001	1 00:07		0.54	
P_18	PUMP	0.000	0 00:00		0.00	
P_36	PUMP	0.023	0 12:38		0.78	
P_SW	PUMP	0.002	1 01:02		0.96	
P19_CE	PUMP	0.000	0 00:00		0.00	
P2_CE	PUMP	0.012	1 00:10		0.60	
W14_18	WEIR	0.000	0 00:00			0.00
C1_2	DUMMY	0.000	3 00:00			
C17_1	DUMMY	0.001	1 00:13			
P_16	DUMMY	0.024	0 16:49			
Spiilway	DUMMY	0.000	0 00:00			

```
***************************
Flow Classification Summary
***************************
```

Conduit	Adjusted /Actual Length	Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Norm Ltd	Inlet Ctrl
		---------- Fraction of Time in Flow Class ----------								

```
*************************
Conduit Surcharge Summary
*************************
```

No conduits were surcharged.

```
***************
Pumping Summary
***************
```

Pump	Percent Utilized	Number of Start-Ups	Min Flow CMS	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr	Power Usage Kw-hr	% Time Off Pump Curve Low	% Time Off Pump Curve High
P_13	97.08	1	0.00	0.00	0.00	0.118	0.24	0.0	0.0
P_18	0.00	0	0.00	0.00	0.00	0.000	0.00	0.0	0.0
P_36	99.29	1	0.00	0.01	0.02	3.233	3.45	0.0	0.0
P_SW	97.28	1	0.00	0.00	0.00	0.446	1.88	0.0	0.0
P19_CE	0.00	0	0.00	0.00	0.00	0.000	0.00	0.0	0.0
P2_CE	98.45	1	0.00	0.01	0.01	2.598	16.40	0.0	0.0

```
Analysis begun on:  Tue Mar 21 15:02:21 2017
Analysis ended on:  Tue Mar 21 15:02:23 2017
Total elapsed time: 00:00:02
```

Appendix B Westhoff Water Balance Model In and Output

Westhoff developed a custom water balance model, **Westhoff Water Balance (WesthoffWB)**, using a dynamic, continuous flow system simulation software known as GoldSim. The model is composed of various model elements to portray the physical properties of natural and man-made systems involved in water management as well as various data sets to represent climate and environmental information. The model is simulated on a daily basis over a timespan corresponding to the climate time series. Time series results of state variables (flows at various strategic locations of the system and water levels at various water bodies) are exported and analyzed.

Overview of GoldSim Elements Used in WesthoffWB

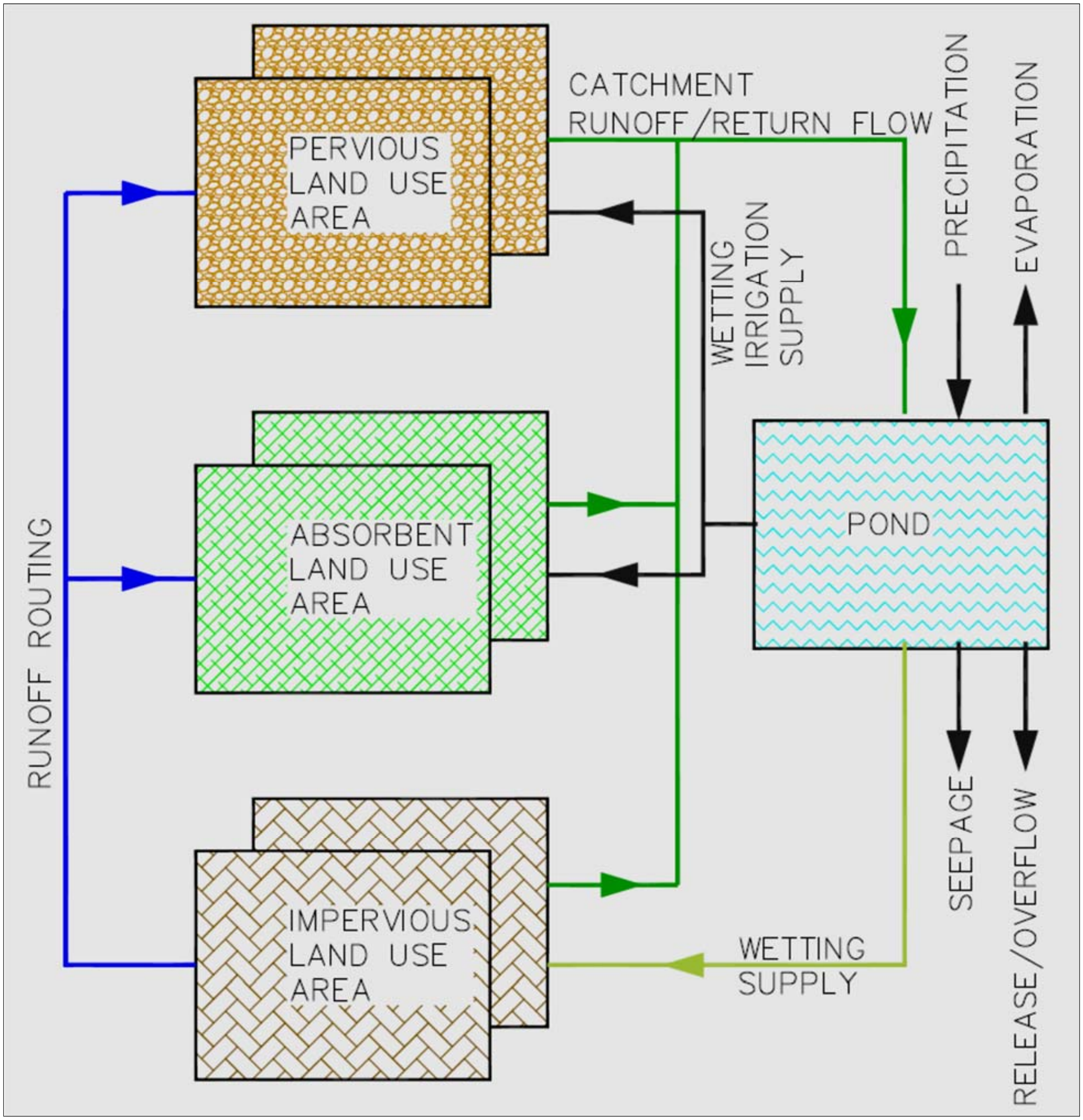
The GoldSim software supports integration of multiple instances of the following elements, among others, to develop a water balance model:

- Reservoir elements: to provide solution of the differential form of water balance equation incorporating change in volume and rates of inflow and outflow;
- Function elements: to link state variables to other state variables and data using applicable mathematical operations;
- Single Data elements: to provide the value of a single parameter;
- Time series data elements: to provide time series data, especially climate and meteorological data;
- Look-up data elements: to provide extraction/ interpolation of the value of a dependent variable using an input value of the independent variable from a tabular data set;
- Script elements: to provide custom functions and data processing not included in the basic GoldSim computational engine; and,
- Results elements: to provide tabular and graphical output of state variables and variables derived from them.

WesthoffWB Model Overview

The model is a systematic arrangement of various elements to depict catchment configuration consisting of multiple ponds and various land-use areas drainage from the impervious land-use areas can be optionally routed to other land-use areas before being drained to a pond. Additionally, the model allows irrigation/ recycle water supply from the pond at a constant or variable rates. Figure B1 shows the schematic of a typical pond/land-use components.

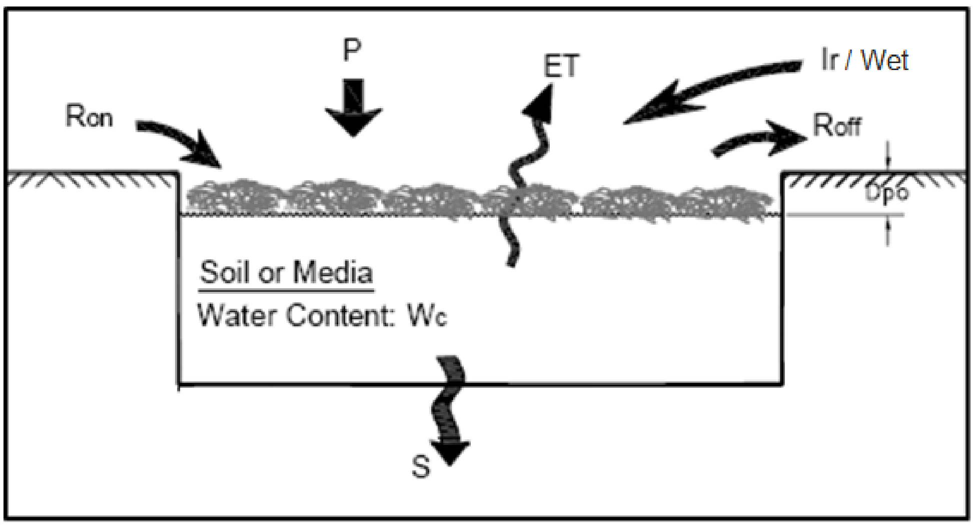
Figure B1 Water Balance Model Components



Modeling of Pervious and Absorbent Land Use Areas

The pervious and absorbent land-use areas cut back significant portion of inflow (precipitation and upstream run-on) in the form of evaporation and infiltration, and allow change in soil water content. Runoff from these land-use areas is determined by using the soil water balance concept. The change is soil water content and the rates of evaporation and infiltration are determined using the physical properties of soil as well as the climate parameters. Figure B2 illustrates the water balance concept of pervious/ absorbent soil mass. Typical formulation of soil surface, for example compacted gravel, can be supplied with excess amount of water (wetting) to enhance evaporation loss. When irrigation is considered within pervious or absorbent land-use areas, water loss to environment through evapotranspiration is possible; however, a portion of irrigation supply would return as runoff subject to the physical properties of soil. Equation 1 is used in evaluating soil water balance.

Figure B2 Soil Water Balance



$$\frac{\Delta W_C}{\Delta t} = P + R_{on} + Ir + Wet - ET - S - R_{off} \quad (1)$$

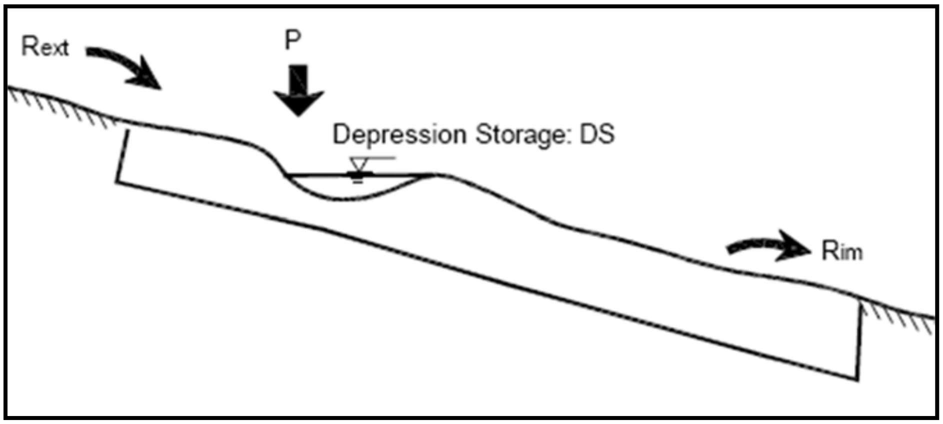
Where,

W_C	Soil water (mm)
Δt	Time interval (1 day)
P	Precipitation (mm)
R_{on}	Run-on (mm)
Ir or Wet	Irrigation or Wetting supply (mm)
ET	Evapo-transpiration (mm)
S	Seepage (mm)

Modeling of Impervious Land Use Areas

Water loss from impervious land-use areas is accounted for as a constant initial abstraction (depression loss) or as evaporation/ infiltration from wetted surface. Figure B3 shows the water balance concept of impervious land-use areas using the depression loss approach. Equation 2 illustrates this concept mathematically.

Figure B3 Water Balance of Impervious Land-use Areas



$$R_{im}(i) = P(i) + R_{ext}(i) - D_S \quad (2)$$

Where:

R_{im}	Runoff from impervious area (mm)
R_{ext}	Run-on from external areas, if any (mm)
D_s	Depression storage (mm)
P	Precipitation (mm)

In the impervious surface wetting approach, it is assumed that extra wetting water is supplied to the surface to form a thin layer of water, from which evaporation and infiltration will take place. Governing equations for the infiltration and evaporation process are provided as follows (Mansell and Roller, 2008). The infiltration rate is estimated by Equation 3:

$$I = ki * (1 - S/Smax) \quad (3)$$

Where:

I	Infiltration rate (mm)
ki	Empirical coefficient
S	Storage on surface at any time (mm)
$Smax$	Storage capacity on surface (mm)

Equation 4 illustrates the water surface evaporation on a rainy day, and Equation 5 estimates evaporation on a dry day.

$$E = kr * E_o \quad (3)$$

$$E = kd * E_o \quad (4)$$

Where:

E	evaporation rate (mm)
Kr, kd	Empirical coefficients
E_o	Reference crop evapo transpiration(mm)

Data Requirement

The model requires the following set of data for simulation:

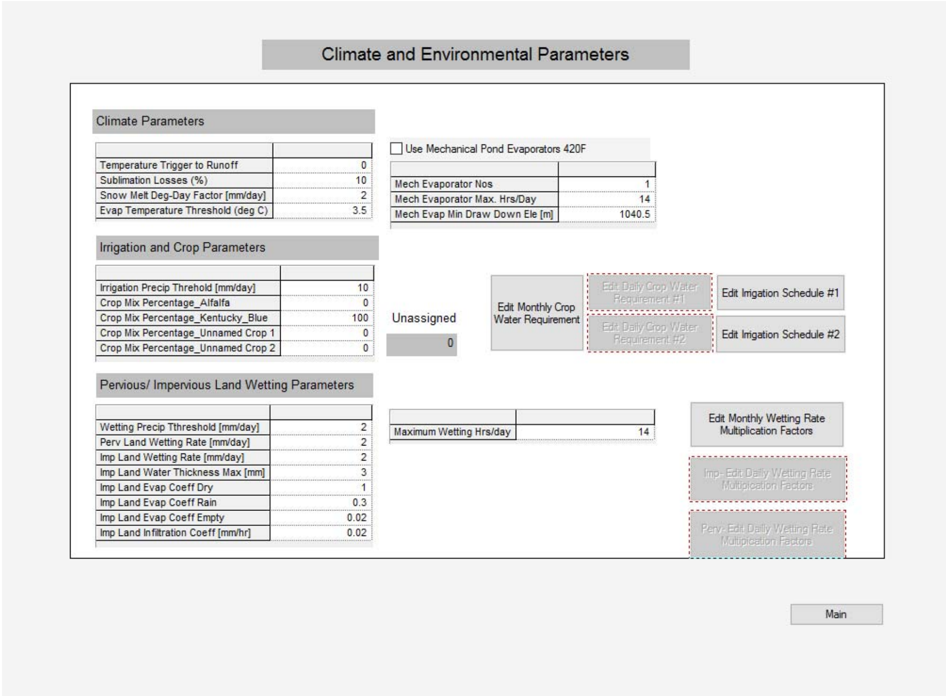
- Climatic/ meteorological time series data such as temperature, precipitation, and evaporation;
- Parameters such as the degree-day factor (to account for snow-melt) and sublimation loss factor;
- Irrigation crop water requirement for various crops and the precipitation threshold to apply irrigation;
- Parameters to determine evaporation/ infiltration from wetted impervious surfaces;
- Irrigation and wetting schedules;
- Physical properties of pervious/ absorbent soil surfaces such as composition (sand, silt, clay etc.), porosity, field capacity, wilting point, soil depth, and hydraulic conductivity;
- Percentages of runoff from impervious land-use areas routed to pervious/ absorbent land-use areas;
- Elevation – area – volume and elevation – spill discharge relationship tables for pond;
- Operating rule levels for pond such as, high water level, upper normal water level, and lower normal water level;
- Seepage and groundwater parameter for pond; and,
- Recycle flow rate and recycling schedule

The model data and simulation operations entered are shown in Figures B4 through B8 for various model input components.

Results

Simulation results from the WesthoffWB model consists of a set of time series of state or derived variables. These can be viewed as graphs and tables, or exported to other applications such as Excel. Figures B9 and B10 show the summary output for Ponds 2 and Pond Central. Figures B11 to B19 show the model output as a time series for the rest of the ponds including the simulated water elevation and the HWL mark.

Figure B4 Climate and Environmental Parameters



Climate and Environmental Parameters

Climate Parameters

Temperature Trigger to Runoff	0
Sublimation Losses (%)	10
Snow Melt Deg-Day Factor [mm/day]	2
Evap Temperature Threshold (deg C)	3.5

☐ Use Mechanical Pond Evaporators 420F

Mech Evaporator Nos	1
Mech Evaporator Max. Hrs/Day	14
Mech Evap Min Draw Down Ele [m]	1040.5

Irrigation and Crop Parameters

Irrigation Precip Threhold [mm/day]	10
Crop Mix Percentage_Alfalfa	0
Crop Mix Percentage_Kentucky_Blue	100
Crop Mix Percentage_Unnamed Crop 1	0
Crop Mix Percentage_Unnamed Crop 2	0

Unassigned 0

Edit Monthly Crop Water Requirement
Edit Daily Crop Water Requirement #1
Edit Daily Crop Water Requirement #2
Edit Irrigation Schedule #1
Edit Irrigation Schedule #2

Pervious/ Impervious Land Wetting Parameters

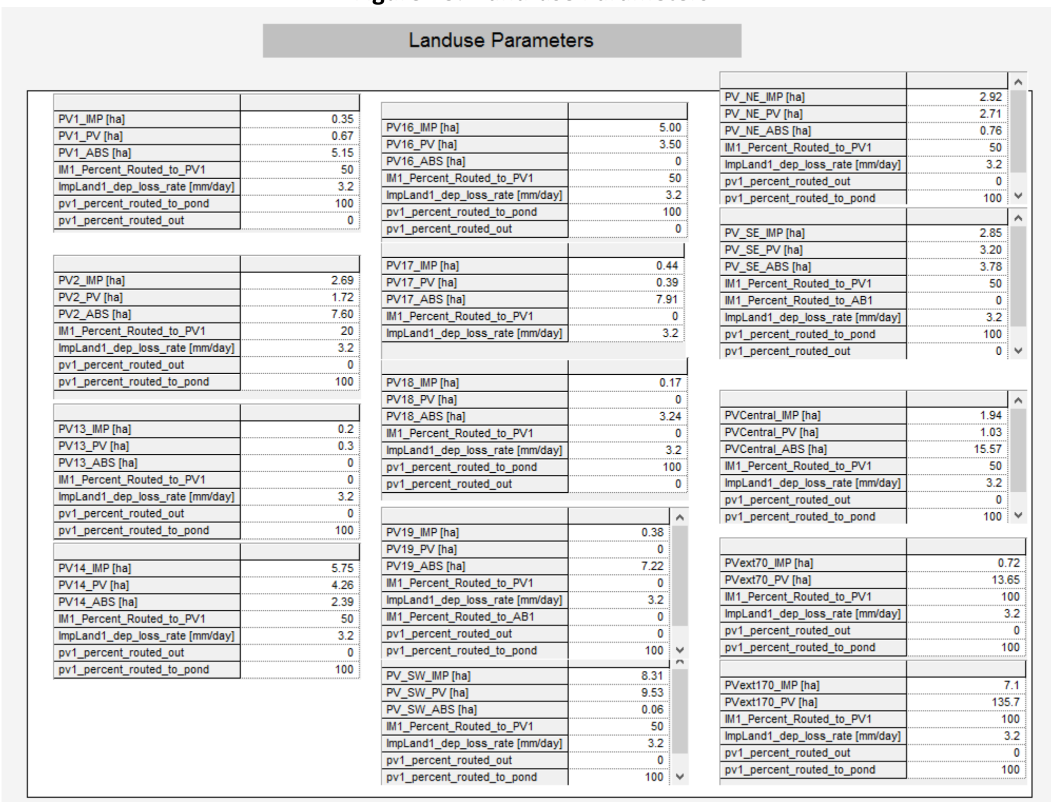
Wetting Precip Tthreshold [mm/day]	2
Perv Land Wetting Rate [mm/day]	2
Imp Land Wetting Rate [mm/day]	2
Imp Land Water Thickness Max [mm]	3
Imp Land Evap Coeff Dry	1
Imp Land Evap Coeff Rain	0.3
Imp Land Evap Coeff Empty	0.02
Imp Land Infiltration Coeff [mm/hr]	0.02

Maximum Wetting Hrs/day	14

Edit Monthly Wetting Rate Multiplication Factors
Imp- Edit Daily Wetting Rate Multipication Factors
Perv- Edit Daily Wetting Rate Multipication Factors

Main

Figure B5. Land-use Parameters



Landuse Parameters

PV1_IMP [ha]	0.35
PV1_PV [ha]	0.67
PV1_ABS [ha]	5.15
IM1_Percent_Routed_to_PV1	50
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_to_pond	100
pv1_percent_routed_out	0
PV2_IMP [ha]	2.69
PV2_PV [ha]	1.72
PV2_ABS [ha]	7.60
IM1_Percent_Routed_to_PV1	20
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_out	0
pv1_percent_routed_to_pond	100
PV13_IMP [ha]	0.2
PV13_PV [ha]	0.3
PV13_ABS [ha]	0
IM1_Percent_Routed_to_PV1	0
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_out	0
pv1_percent_routed_to_pond	100
PV14_IMP [ha]	5.75
PV14_PV [ha]	4.26
PV14_ABS [ha]	2.39
IM1_Percent_Routed_to_PV1	50
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_out	0
pv1_percent_routed_to_pond	100
PV16_IMP [ha]	5.00
PV16_PV [ha]	3.50
PV16_ABS [ha]	0
IM1_Percent_Routed_to_PV1	50
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_to_pond	100
pv1_percent_routed_out	0
PV17_IMP [ha]	0.44
PV17_PV [ha]	0.39
PV17_ABS [ha]	7.91
IM1_Percent_Routed_to_PV1	0
ImpLand1_dep_loss_rate [mm/day]	3.2
PV18_IMP [ha]	0.17
PV18_PV [ha]	0
PV18_ABS [ha]	3.24
IM1_Percent_Routed_to_PV1	0
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_to_pond	100
pv1_percent_routed_out	0
PV19_IMP [ha]	0.38
PV19_PV [ha]	0
PV19_ABS [ha]	7.22
IM1_Percent_Routed_to_PV1	0
ImpLand1_dep_loss_rate [mm/day]	3.2
IM1_Percent_Routed_to_AB1	0
pv1_percent_routed_out	0
pv1_percent_routed_to_pond	100
PV_SW_IMP [ha]	8.31
PV_SW_PV [ha]	9.53
PV_SW_ABS [ha]	0.06
IM1_Percent_Routed_to_PV1	50
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_out	0
pv1_percent_routed_to_pond	100
PV_NE_IMP [ha]	2.92
PV_NE_PV [ha]	2.71
PV_NE_ABS [ha]	0.76
IM1_Percent_Routed_to_PV1	50
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_out	0
pv1_percent_routed_to_pond	100
PV_SE_IMP [ha]	2.85
PV_SE_PV [ha]	3.20
PV_SE_ABS [ha]	3.78
IM1_Percent_Routed_to_PV1	50
IM1_Percent_Routed_to_AB1	0
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_to_pond	100
pv1_percent_routed_out	0
PVCentral_IMP [ha]	1.94
PVCentral_PV [ha]	1.03
PVCentral_ABS [ha]	15.57
IM1_Percent_Routed_to_PV1	50
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_out	0
pv1_percent_routed_to_pond	100
PVext70_IMP [ha]	0.72
PVext70_PV [ha]	13.65
IM1_Percent_Routed_to_PV1	100
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_out	0
pv1_percent_routed_to_pond	100
PVext170_IMP [ha]	7.1
PVext170_PV [ha]	135.7
IM1_Percent_Routed_to_PV1	100
ImpLand1_dep_loss_rate [mm/day]	3.2
pv1_percent_routed_out	0
pv1_percent_routed_to_pond	100

Figure B6. Soil Parameters for AB1 and PV1

Parameter	Unit	Value
Soil Depth	mm	200-250
Compostion: silt	%	100
Porosity	-	0.482
Field Capacity	-	0.316
Wilting Point	-	0.063
Saturated Hydraulic Conductivity	m/s	5.26e-06
Sub-Soil Hydraulic Conductivity	m/s	5.78e-07

Figure B7. Pump rates

Pump Parameters

Pump_cap_P1 [L/s]	0.5
Pump_capP2 [L/s]	20
Pump_capP13 [L/s]	1
Pump_capa_P14 [L/s]	0.5
Pump_capP18 [L/s]	5
Pump_capP19 [L/s]	5
Pump_cap_NE [L/s]	2
Pump_cap_SW [L/s]	2

Figure B8. Irrigation Schedule

Irri Parameters

ABs1_irropt	4
ABs2_irropt	4
abs17	4
absSW	4
absSE	4
absNE	4
absCentral	4
abs19	4
abs13	4
abs14	4
abs18	4

3: Generic Irrigation

4: Golf Course Irrigation

Results

Figure B9. Result Summary for Pond 2

POND 2

	Area	12.01	ha - TOTAL									
	MAX	MIN	AVG	MEDIAN								
VOLUME (m^3)	25322	4312	4929	4948								
LEVEL (m)	3.4	0.9	1.0	1.0		UNIT AREA RESULTS BASED ON TOTAL CATCHMENT SIZE				RESULTS BASED ON TOTAL CATCHMENT SIZE AND POND		
	MAX	TOTAL	AVG	MEDIAN		MAX	TOTAL	AVG	MEDIAN	MAX	TOTAL	AVG
CATCHMENT INFLOW (m^3)	5190	33620	600	0	(mm)	43.2	279.9	5.0	0.0	43.2	279.9	5.0
DIRECT PRECIPITATION (m^3)	3364	131930	2356	3364	(mm)	28.0	1098.5	19.6	28.0	28.0	1098.5	19.6
EVAPORATION LOSS (m^3)	3219	131313	2345	3219	(mm)	26.8	1093.4	19.5	26.8	26.8	1093.4	19.5
GROUNDWATER INFLOW (m^3)	0	0	0	0								
SEEPAGE LOSS (m^3)	0	0	0	0	(mm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DISCHARGE (m^3)	27799	283333	5060	27799	(mm)	231.5	2359.1	42.13	231.5	231.5	2359.1	42.1
OVERFLOW (m^3)	0	0	0	0	(mm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irrigation Supply (m^3)	0	0	0	0								
Wetting Supply to Pervious Area (m^3)	0	0	0	0								
Wetting Supply to Impervious Area (m^3)	0	0	0	0								
Recycle Flow (m3)	0	0	0	0								
Mechanical Evaporation Loss (m3)	0	0	0	0								
External Inflow (m3)	22667	249096	4448	22667								
Pond Emptying Outflow (m3)	0	0	0	0								
WATER BALANCE (m^3)		0.000										

Link from Goldsim (don't change location):

Drainage Areas:	[ha]	[Irrigation or Wetting]
IM1	2.6900	1 No irrigation/wetting
PV1	1.7200	1 No irrigation/wetting
AB1	7.6000	4 Golf Course Irrigation

Pond:	[m]	[m3]
Bottom	0.00	0.0
LNWL	1.00	4948.0
UNWL	1.00	4948.0
HWL	3.60	27953.0
Start Elev.	1.00	4948.0
End Elev.	1.00	4948.0

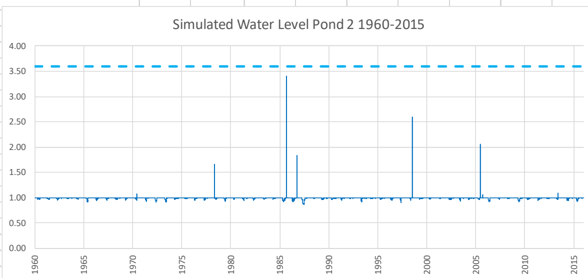


Figure B10. Result Summary for Pond Central (CN)

POND CN

	Area	18.54	ha - TOTAL									
	MAX	MIN	AVG	MEDIAN								
VOLUME (m^3)	40580	4779	7665	6472								
LEVEL (m)	3.0	0.5	0.7	0.6		UNIT AREA RESULTS BASED ON TOTAL CATCHMENT SIZE				RESULTS BASED ON TOTAL CATCHMENT SIZE AND POND		
	MAX	TOTAL	AVG	MEDIAN		MAX	TOTAL	AVG	MEDIAN	MAX	TOTAL	AVG
CATCHMENT INFLOW (m^3)	6573	154805	2764	2405	(mm)	35.5	835.0	14.9	13.0	35.5	835.0	14.9
DIRECT PRECIPITATION (m^3)	6784	234982	4196	4120	(mm)	36.6	1267.4	22.6	22.2	36.6	1267.4	22.6
EVAPORATION LOSS (m^3)	6729	238823	4265	4139	(mm)	36.3	1288.2	23.0	22.3	36.3	1288.2	23.0
GROUNDWATER INFLOW (m^3)	0	0	0	0								
SEEPAGE LOSS (m^3)	0	0	0	0	(mm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DISCHARGE (m^3)	0	0	0	0	(mm)	0.0	0.0	0.00	0.0	0.0	0.0	0.0
OVERFLOW (m^3)	0	0	0	0	(mm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irrigation Supply (m^3)	241708	10202315	182184	177872								
Wetting Supply to Pervious Area (m^3)	0	0	0	0								
Wetting Supply to Impervious Area (m^3)	0	0	0	0	(mm)							
Recycle Flow (m3)	0	0	0	0								
Mechanical Evaporation Loss (m3)	0	0	0	0								
External Inflow (m3)	231279	10052392	179507	175506								
Pond Emptying Outflow (m3)	0	0	0	0								
WATER BALANCE (m^3)		2.1										

Link from Goldsim (don't change location):

Drainage Areas:		[Irrigation or Wetting]
IM1	1.94	1 No irrigation/wetting
PV1	1.03	1 No irrigation/wetting
AB1	15.57	4 Golf Course Irrigation

Pond:	[m]	[m3]
Bottom	0	0
LNWL	0.5	4936
UNWL	3.5	50913
HWL	3.5	50913
Start Ele	1	4936
End Elev	0.60	5974

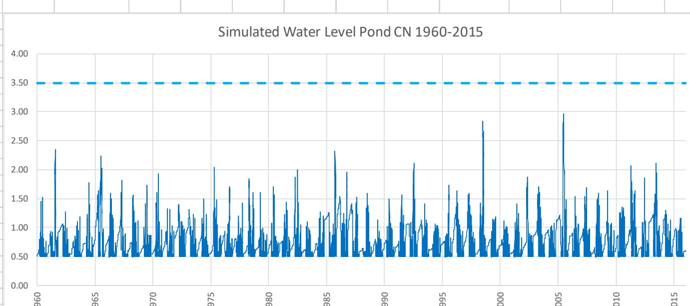


Figure B11. Water Level Pond 1

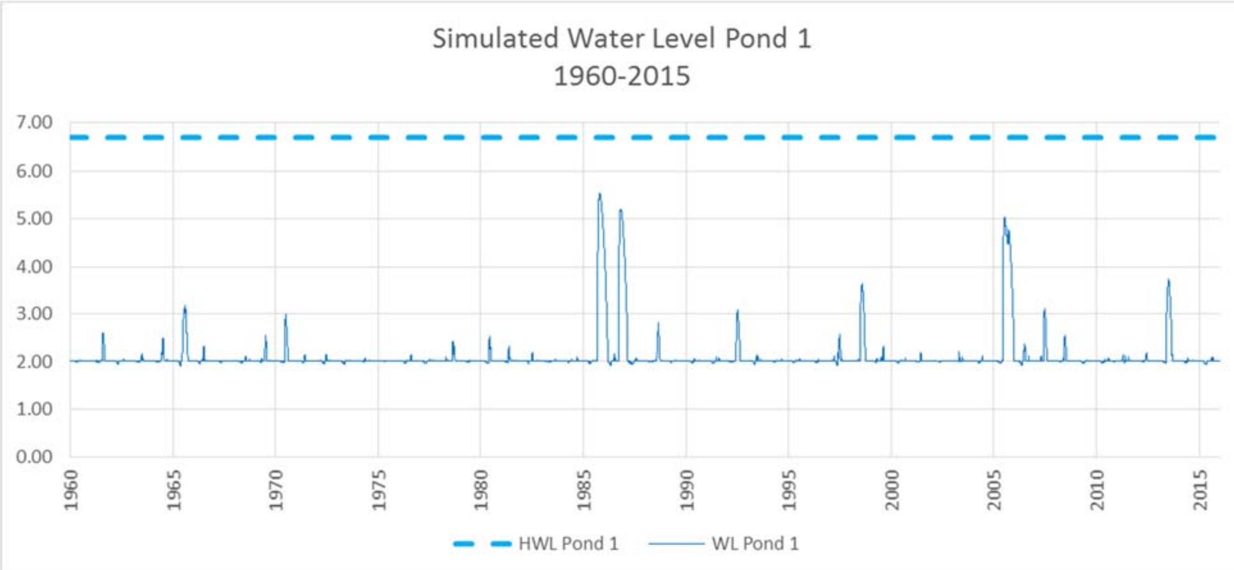


Figure B12. Water Level Pond 13

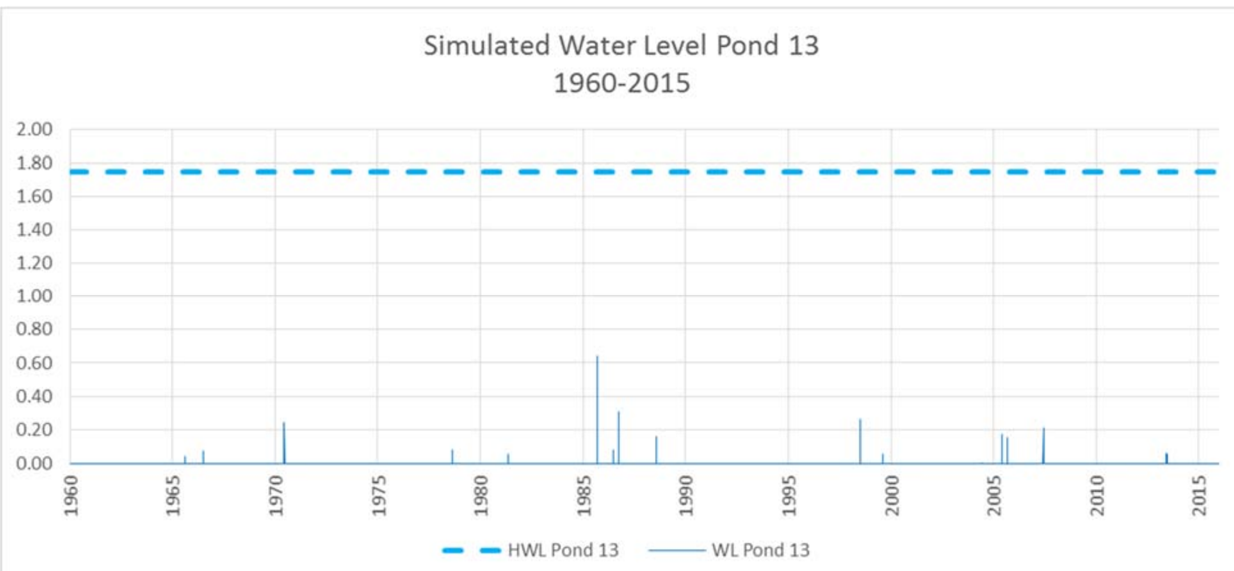


Figure B13. Water Level Pond 14

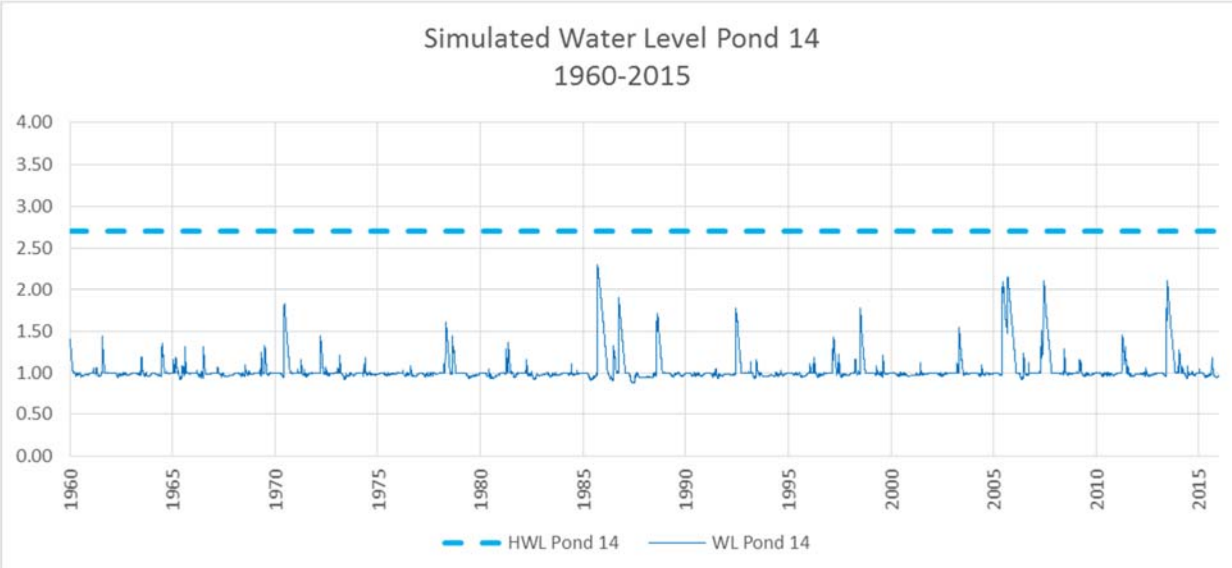


Figure B14. Water Level Pond 16

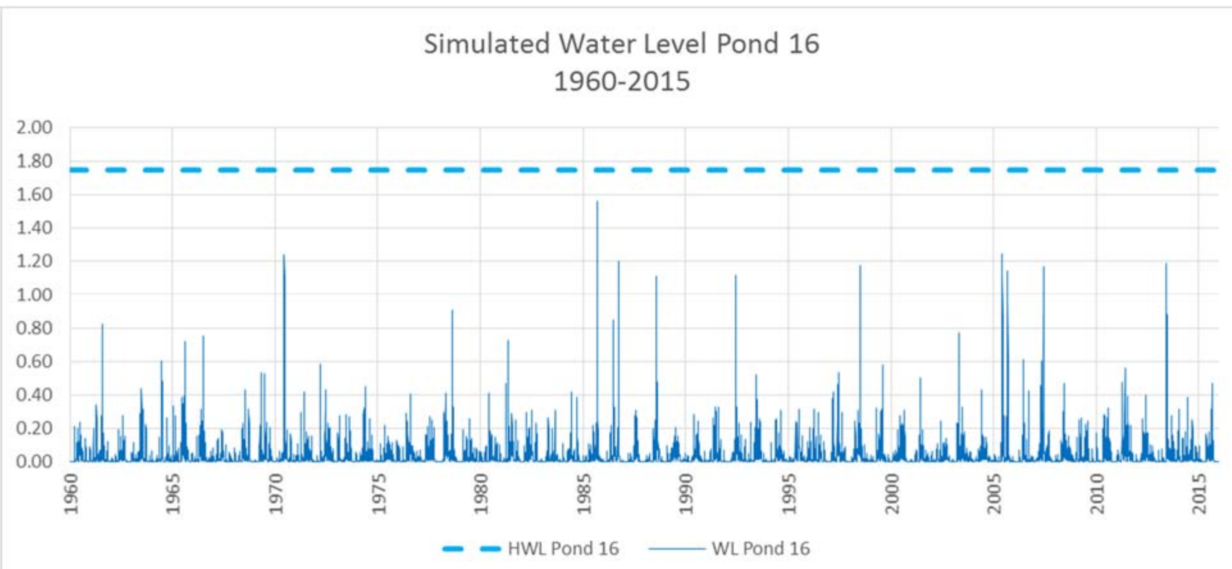


Figure B15. Water Level Pond 17

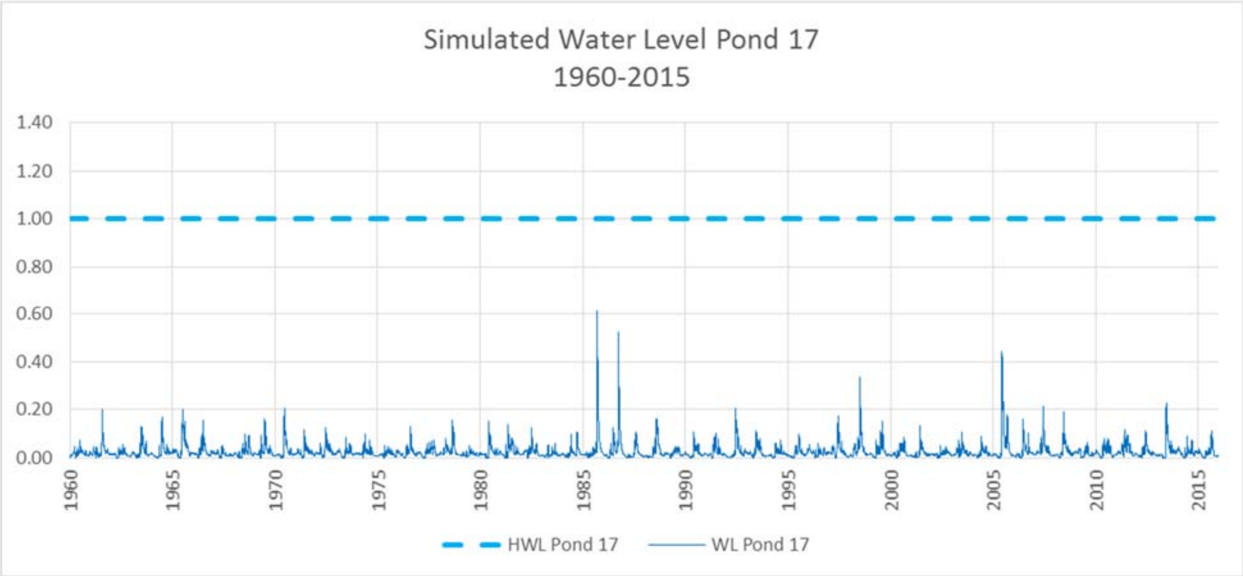


Figure B16. Water Level Pond 18

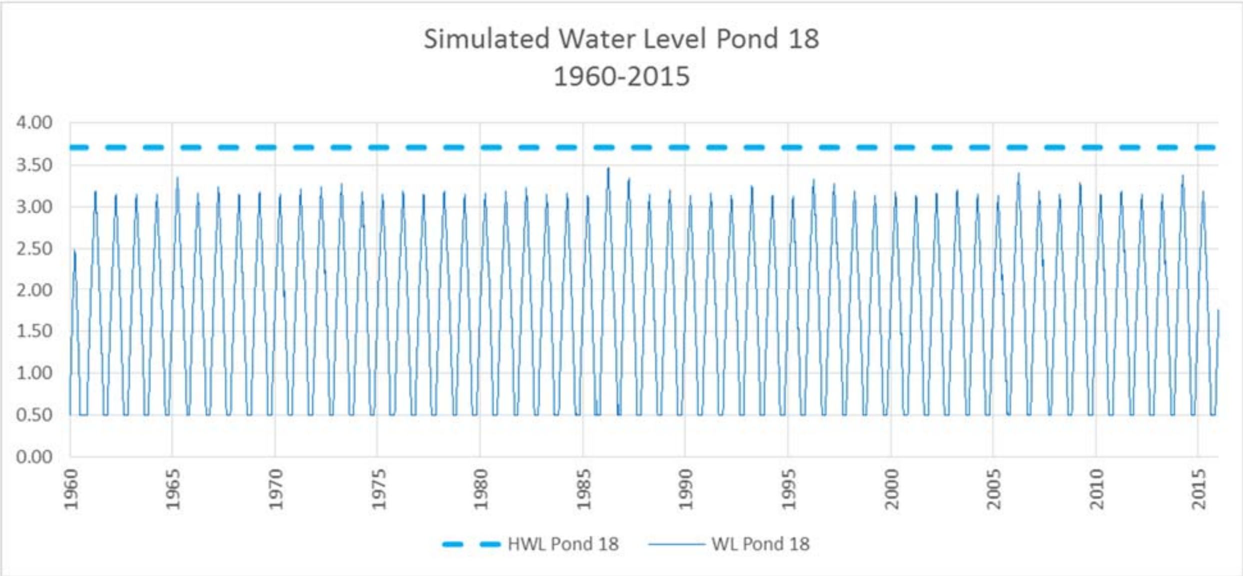


Figure B17. Water Level Pond 19

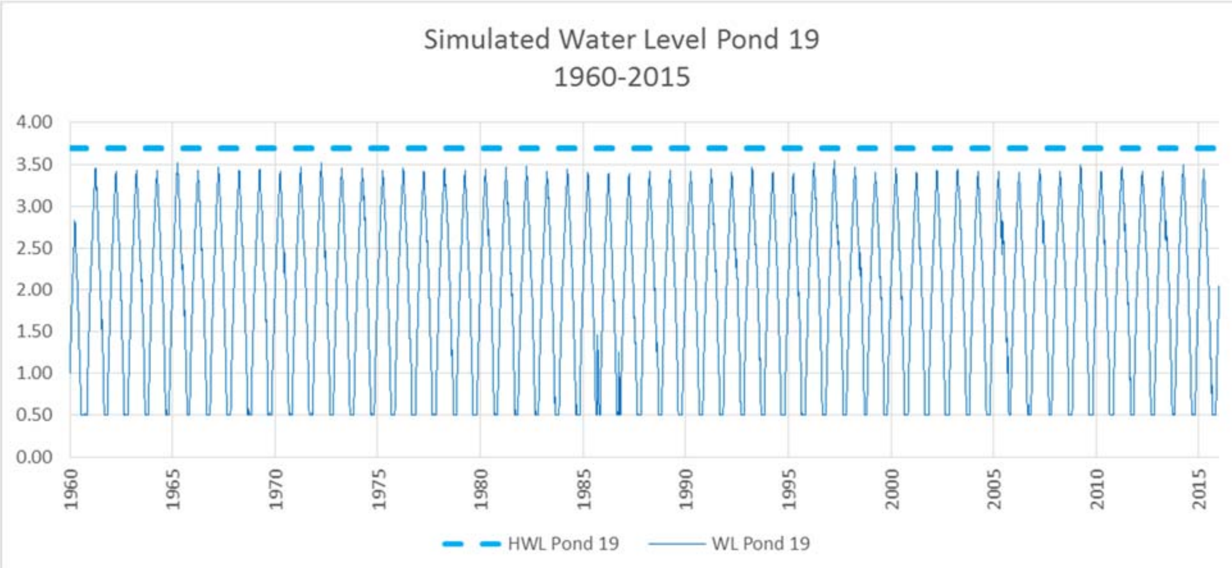


Figure B18. Water Level Pond NE

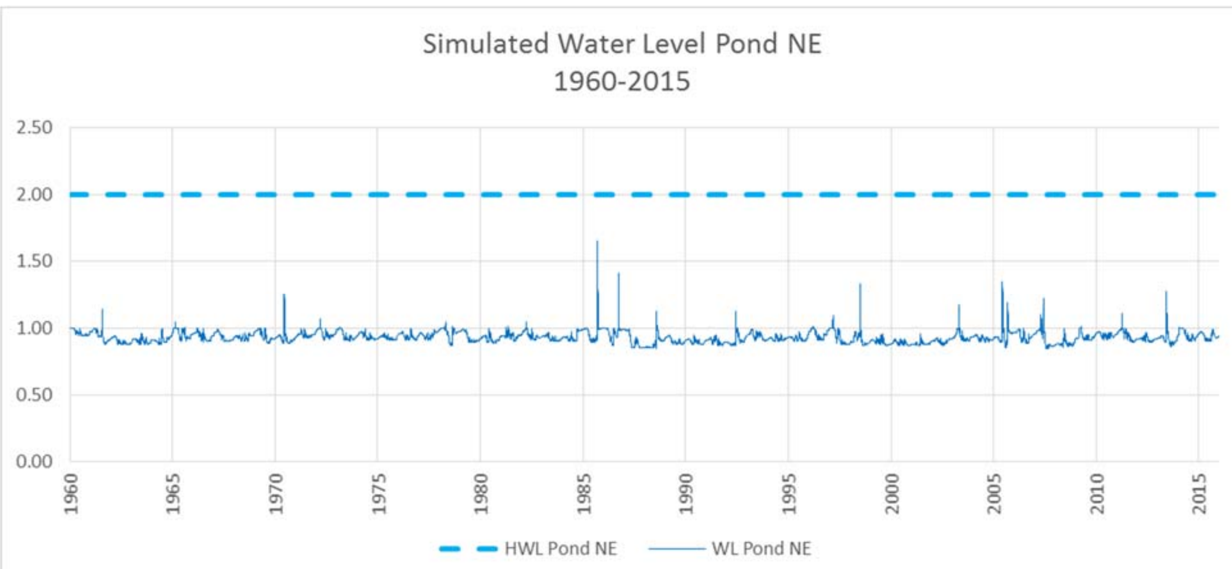


Figure B19. Water Level Pond SW