CHESTER GOLF CLUB

WATER COMMITTEE REPORT

March 25, 2018

Water Committee:

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EXECUTIVE SUMMARY

The Water Committee was formed in late 2016 to review the Club's water situation following the worst drought experienced since we started recording rainfall in 1988. Rainfall was only 48% of normal amounts in 2016, and far less effective than normal as well. Turf was under stress in mid-July. It started to turn brown in mid-July and we experienced some turf loss on our fairways by early August. Some members were puzzled to see the fairways browning while our storage pond remained half full.

The Committee's focus was threefold: (1) Look at what can be done better with the water we already have, (2) Determine what the total water requirements are to maintain the course at the level experienced in 2017, and (3) Identify options to increase water availability, if that is necessary.

We were busy in 2017 researching the science and collecting relevant data. Soils were tested to determine moisture capacity, root depth, and compaction. We have studied rainfall patterns for the past 29 years. Water flows were monitored into the storage pond and as it exited from #15 and #10. An analysis was completed to quantify surface runoff that reaches the pond. Another analysis determined how quickly our turf loses water and how much of that loss needs to be replaced to maintain acceptable turfgrass. The pond was surveyed to ensure silting had not impaired our storage capacity. The original engineer was asked to complete as-built drawings of the pond and provide water volume remaining at each elevation. We examined our irrigation system, spray coverage, and irrigation practices. At year-end, the pond was drained to assess groundwater recharge potential (and unexpectedly repair the intake screen). We now know a lot more than we knew in August 2016.

Some significant new practices were adopted over the past year to improve turfgrass at Chester:

1) Our new $53,000 AERO-Vator machine has been used at least twice on all mown rough and fairways. Its purpose is to reduce soil compaction, allowing water, nutrients and oxygen into a deeper root zone. If our soil is compacted, water tends to run off and is wasted; roots are shallow, and our soil moisture reservoir is minimized.
2) Irrigation Audits are now standard practice. There are fewer unpleasant surprises just when you most need a fully functioning system. A number of these occurred in 2016 at vulnerable times for our turf. Audits have also allowed us to alter flow from some nozzles so that water is not sprayed on non-essential areas.
3) A TDR Moisture Reader was acquired to help monitor soil moisture levels and assist in identifying stressed turfgrass before it becomes too late to prevent turf loss.
4) We have established target moisture levels in the grass root zone that minimize water requirements while maintaining adequate quality.

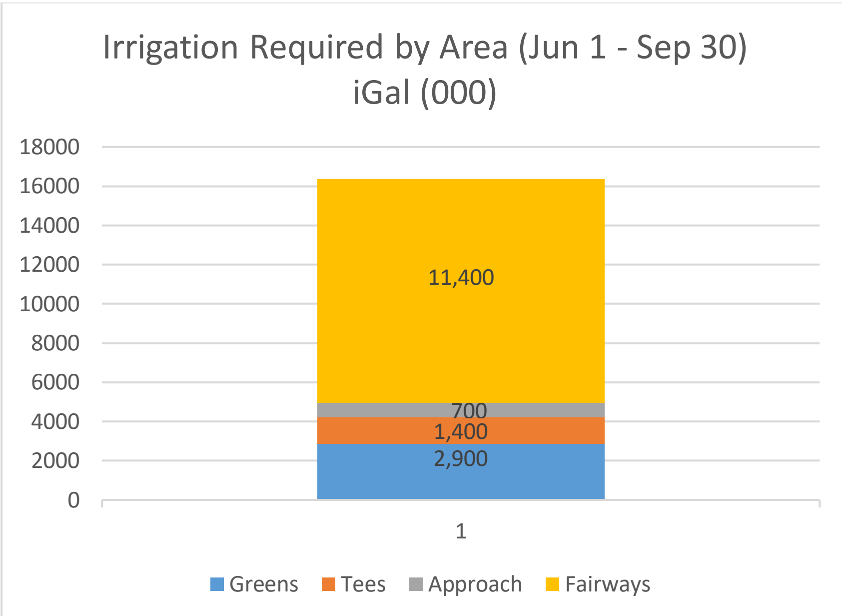
There are 50 acres of irrigated turf at Chester. Direct rainfall has always been our main source of irrigation water, historically providing about 75% of our turf needs. The remaining 25% comes from our storage pond. But rainfall is fickle and much less effective at putting water into the root zone – the only place that matters to our grasses. Too often, the rain is wasted because it is too little, too much, or not needed at all. Our irrigation system is more effective than rainfall in supplying water because it can supply water when needed, in amounts that are useful to the grass roots. Despite rainfall being less effective, when it is plentiful and timely, we don't need a lot of make-up water from the pond. In drought years, however, there may not be enough pond water to cover the shortfall. Turf will become stressed and start to turn brown. Our numerous grass varieties will all go dormant. Some will survive for many weeks in the dormant phase; those with shallow roots and low stress tolerance (Poa Annua) will die quickly and there is turf loss. Dormant, brown turf can be merely an esthetic issue that is soon corrected when rainfall returns, or it can grow to become a more serious turf loss issue that will need the fall and spring to fully repair itself.

The priority in allocating irrigation water has been Greens, Tees, and Approaches. Fairways are the last priority. The first group has a bigger impact on play and costs more to fix (typically these areas need resodding). Fairways cost little to fix when there is turf loss, as they will self-repair with time if damage isn't too widespread.

Our main irrigation season is the four months from June 1 to September 30. Our pond is normally full on June 1 and our requirements fall off dramatically in October. We are therefore focusing on the four-month period.

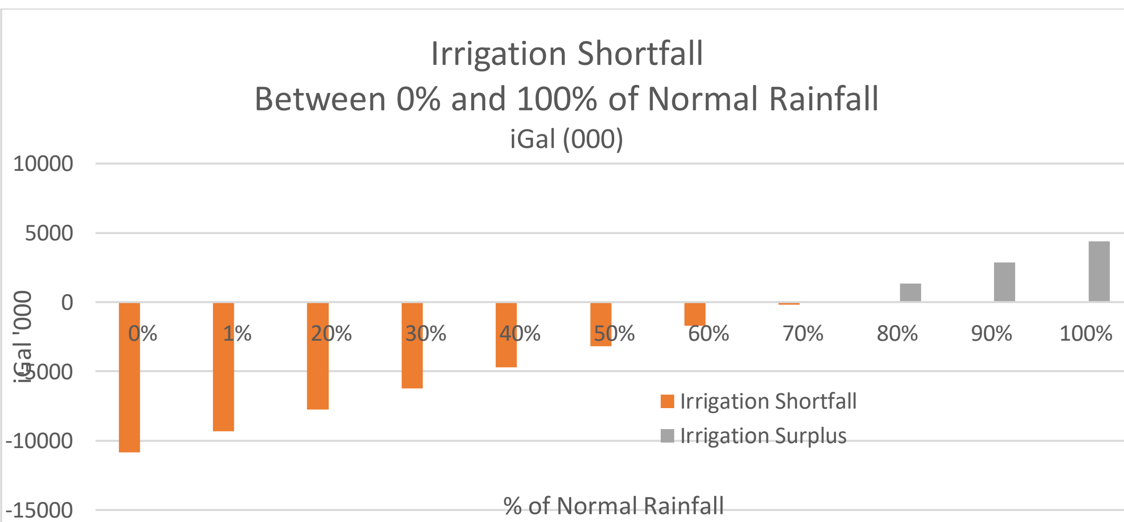
As irrigation and rainfall deliver water with different effectiveness (70% and 53% respectively), it is easier to start the discussion of water requirements in terms of irrigation equivalents. This is the amount of irrigation required if there was no rain. This number is then adjusted downward to reflect the contribution of rain at different rainfall levels.

The total irrigation (Jun 1-Sep 30) required to maintain our course at 2017 levels of conditioning is estimated to be approximately 16,400,000 imperial gallons (igal). Of this, 5,000,000 igal is for Greens, Tees, and Approaches. The lion's share remaining (11,400,000 igal) is required for Fairways.



The amount of irrigation required decreases as rainfall increases. As rainfall increases, runoff and groundwater recharge also increase into the pond, boosting our capacity to extract irrigation water.

With no rain and a pond capacity of only 6,370,000 igal, we have inadequate capacity to irrigate the course to a level of 16,400,000 igal. Our irrigation shortfall decreases as we get closer to normal rainfall levels.



Times Occurring in last 29 Years.......

											110%+
0	***0***	***0***	***0***	***1***	***1***	***0***	***2***	***4***	***3***	***7***	***11***
				(2016)	***(2005)***		***(1997, 2008)***				

Based on our current capacity and practices, two years in twenty-nine (7%) would be difficult years with turf loss, while another two years (7%) would challenge our ability to maintain adequate turfgrass conditions and fully deplete any reserve for Greens and Tees by mid-September. In the case of the two years that received 70% of normal rainfall, we might have been able to adequately irrigate throughout much of the playing season and allowed the fairways to become dry in September.

In 2016, the onset of turf damage could have been delayed by a couple of weeks to mid-August by the timely application of another 1,500,000 igal of the reserve held back for priority Greens, Tees, and Approaches. That is one thing we would do differently today – knowing pond recharge rates and the capacity of the pond. We would keep six weeks supply for the priority areas (1,500,000 + 300,000 recharge) and release the rest for fairway watering. We should all recognize that six weeks reserve for priority areas may not be enough if the drought is prolonged; there remains in that case, some risk of turf loss on our tees and greens.

Eliminating all possibility of turf loss is difficult to attain without adding sufficient storage capacity to buffer all low rainfall scenarios. Receiving four months' worth of rainfall at the beginning and end of our irrigation season has the same effect as a four-month drought with no rain at all.

If we do nothing but manage our resources with the benefit of what we have learned and adopted since the 2016 drought, there may still be one year in ten when we will experience turf loss. However, we can delay it further into the playing season and thereby enjoy good conditions longer. Also, we know the damage will self-repair as it did in the Fall and Spring of 2016/17, with little extra cost to our maintenance budget. The impact on our maintenance budget in 2016 was only $1,000 worth of extra grass seed and peat moss, plus another $1,000 in labour allocated from our existing crew. Most of the repair work was done by Mother Nature.

If we wish to maintain our course at 2017 levels during a drought year like 2016, we will need to add water storage capacity. Another 4,000,000 igal would protect us against the worst drought in our recorded history. This might be reduced as we experiment with some of the options yet to be explored – such as reduced flow to certain fairway areas or pushing the envelope further in deficit irrigation.

If the Board and membership feel that course conditions like the 2016 season merit the *immediate* expenditure of capital funds to avoid a repeat, then we have identified some options we feel are worth pursuing further with the help of an engineering firm experienced in this area. It will also require consultation with NS Environment, as wetlands and existing watercourses are involved.

MAIN REPORT

The Green Committee undertook to review the water situation at Chester in response to the difficulties the Club experienced during the drought period in 2016. This drought was felt across Nova Scotia, but the worst conditions were seen along the southwest coast. Our course showed signs of severe dryness from mid-July until late September, when rainfall resumed, and the days grew cooler. During the drought, our fairways turned brown and there was turf loss.

At our AGM in August 2016, we advised the membership that a Water Committee would be formed to investigate and make recommendations to the membership by the Fall of 2017.

***INTRODUCTION*:**

Chester Golf Club is a popular seaside course that hosts 32,000 rounds of golf per year. Its location by the water brings cooling winds to help keep the temperatures down in summer. These same winds also remove moisture from our course and contribute to turf problems in exposed areas.

Rainfall in the area has historically been sufficient to provide much of our water requirements, and with supplemental irrigation, provide adequate moisture for reasonably healthy turf. However, there have been years where rainfall has been minimal, and irrigation insufficient, to prevent browning of turf and occasional turf loss. Smoking bans have even been put in place to reduce the fire hazard. If the browning of turf is short-lived and rainfall returns, there has been little damage. If the browning is over a longer period and our grass plants die, turf damage can be readily apparent. Even if there is sufficient moisture, high temperatures alone can kill our grass.

In 2004, our irrigation pond was expanded to hold 6,370,000 *imperial gals (igal)*. This was meant to allow five weeks of full irrigation of 25mm/week in a dry summer. In 2007, installation of our new irrigation system was completed. This allowed for automated irrigation of fairways and improved coverage of tees and greens.

Then in 2016, we were hit with the most severe drought experienced in the 29 years that rainfall records have been kept here in Chester. Rainfall for the June through September irrigation period equaled 48% of the average. On our 50 irrigated acres, this translates to a shortfall of over 6,300,000 igal that must now be added to the irrigation we already use. It was believed that our current pond wouldn't have come close to providing this amount, even if we eliminated any reserve and drained the pond completely (more on reserve later).

As with earlier droughts, our watering priorities in 2016 favoured greens, tees, and approaches to minimize any impact on play. And we are fortunate that the turf grass on our fairways repairs itself relatively quickly when rain finally returns in the fall and spring. This healing process repeated itself in 2016 and early 2017. By June/17, our fairways were in excellent condition.

This report will look at what we might do differently in the future with existing water resources to minimize the impact of a 2016 type drought. It will also look at potential water requirements and best practices, and explore options available to us to improve turf grass in Chester.

***IRRIGATION SYSTEM*:**

Pumping - A new pumping system was installed in 2004 to extract water from our newly expanded pond and feed the planned irrigation system later installed in 2007.
Twin Gould pumps capable of 800 usgal/min at 125 psi are more than capable of driving an eight-hour irrigation cycle. The system also included a new pump house and electrical work.
While there was an electrical issue preventing the pumps from operating at 100% of capacity, our outside consultant eventually located the problem and it had little impact on the 2016 irrigation season. It has been tested several times since at full capacity (approximately 213,000 igal/night). Seldom do we apply more than 70% of its capability.

Distribution System - The basis of our irrigation system design was an industry rule-of-thumb that allows 25mm/week to all irrigated areas of the course. This figure is often quoted as appropriate for our climate.
Our Rain Bird irrigation system was purchased from MacDonald Irrigation, who completed the installation in early 2007. It is a computer-controlled system with 451 impact spray heads operating at 80 psi. Fairways have either one or two rows of spray heads. These heads are located to supply overlapping circular spray patterns that ensure our fairways receive acceptable uniformity of coverage. The circular spray pattern means that any spray head located close to the side of a fairway is also irrigating our rough; in fact, as much as 50% of the spray can fall on the rough adjacent to some fairways.
Chester has 20 acres of closely mown fairway and another 3 acres of rough that falls within our fairway spray grid (that we choose not to mow closely). By properly covering these areas with uniform irrigation, we also end up fully irrigating the equivalent of another 14 acres of rough.
While we can adapt some of our spray heads to only spray inwards towards the fairway, this would lead to non-irrigated hard runways on the sides of the softer irrigated fairway. This is undesirable.
Some consideration should be given to shutting off irrigation to areas of rough within the fairway spray grid (old fairway demoted to rough). Having non-irrigated sections of rough in the desired line of play helps the higher handicap player get some extra distance.
Rarely have our fairways received large amounts of irrigation since our new system was installed 10 years ago. Rainfall alone has normally been close to sufficient to maintain adequate appearance.
Much work was done in 2016 to ensure that irrigation heads are operating as intended. There were both electrical and mechanical issues to address, including those arising from a lightning strike! While there were trouble spots, the system was more than capable of delivering the water our course required if there was an unlimited supply of water.

Improvements - An audit of the system was completed in May/17 to ensure we have coverage in all areas. This involves testing the controllers and spray heads to ensure each is operating as planned. This includes leveling the spray heads and checking spray direction for opportunities to block any flow going to unnecessary areas (rough, walkways, etc.). As a result, about 20 heads have been switched over to 180-degree flow, saving 100,000 igal of irrigation per year.

*APPENDIX CONTENTS – **Irrigation System***

A) GENERAL
B) SPRAY HEAD COUNT/CAPACITY
C) SPRINKLER APPLICATION RATES

CURRENT WATER STORAGE:

Storage Pond - The present pond along #9 was most recently expanded in 2004 at a cost of approximately $250,000 (allowing for turf repairs).

The design was professionally done by MacWilliams Engineering Ltd. and has served us well. The original concept of a larger pond was thought to impact play on #7 and was reduced to the current design which holds 6,370,000 igal.

As-built drawings obtained in September/16 answered any questions as to what can be extracted from the pond. Some highlights of the design are:

- Essentially all the water can be extracted by our pump – only 1% is "stranded" in the bottom of the pond.
- Min depth designed as 10 ft, max depth at pump intake is 13 ft
- Surface area when full - 117,000 sq ft
- Surface area when down 10 ft - 64,000 sq ft
- The side-slopes of the pond are 2:1 (Run:Fall)
- Pond can be drained to the ocean by gravity

We also asked MacWilliams Engineering to give us detailed volume calculations tied to decreasing depths of the pond. We now know the remaining volume at whatever height the water stands.

In May 2017, we completed a survey of the pond to see if there was any evidence of silt build-up that might reduce the depth reflected in the as-built drawing. We can report that the depths are the same as shown on the drawing, so we still have our full storage capacity of 6,370,000 igal.

We should add that MacWilliams Engineering recommended in 2004 that we could increase the pond height by one or two feet to add capacity relatively easily.

Water Balance of the Storage Pond - The pond has historically been full at the start of our primary irrigation season which we consider to be June 1 and running to September 30. Additional irrigation is required before and after this window for greens and tees, but 80% of our irrigation is supplied in the June – September period when we have low rainfall and high temperatures. Our focus needs to be on that period.

All the water in the pond is from precipitation which enters the pond in several ways:

- As direct rainfall or snowfall onto the surface of the pond.
- As stormwater runoff from rainfall or snowmelt, either as overland sheet flow or as concentrated flow in a ditch or pipe into the pond, especially from Holes #3, #6, #7, #11, #12 and from the parking lot.
- As groundwater seeping into the pond from the water table upgrade of the pond, especially #3 and #7.

Water in the pond exits the pond in several ways:

- Pumped into the irrigation system and then sprayed onto the course through sprinklers.
- As overflow when the water level reaches the overflow level in the concrete structure at the south end of the pond, where it flows into a pipe that crosses #8 and #2 and discharges into the ocean.
- As evaporation into the atmosphere, especially during sunny, hot, dry and/or windy weather.
- As seepage into the groundwater table downgrade of the pond, especially at Holes #1, #8, and #9.

For 2016, many of the above factors were measured or can be closely estimated (the "Knowns"). While we cannot quantify the "Unknowns" by individual factor, it is possible to estimate what they are in total.

Water Balance of the Pond - 2016

	Deposit	igal (000) Withdrawal	Balance
Knowns			
Start June 1/16			**6,367**
Automated Irrigation (from CGC computer records)		-4,873	
Hand watering and washing (est)		-83	
Evaporation		-801	
Rainfall on parking lot	160		
Direct rainfall on pond	416		1,186
Calculated Finish Sep 26/16	576	-5,757	1,186
Actual Finish Sep 26/16			**2,151**
Difference due to "Unknowns" (Rounded)			**970 (Favourable)**
Unknowns			
Leakage through wall		?	
Runoff from #12, #11, #6	?		
Surface runoff into pond from #3/7	?		
Recharge with groundwater	?		

In 2017, we monitored the pipe bringing water in from #11. It ran throughout the summer, discharging 480,000 gal into the pond over the full four months. The pipe bringing in water from #12 and #6 brought in 100,000 gals until it trickled to nothing by the end of July.

Water Balance of the Pond - 2017 (not a full four months)

	Deposit	igal (000) Withdrawal	Balance
Knowns			
Start June 6			**6,367**
Automated Irrigation		-5005	1,362
Hand Watering and washing (Estimate)		-25	1,337
Evaporation		-824	513
Runoff from #12, #11, #6	545		1,058
Rainfall on parking lot	295		1,353
Direct Rainfall on pond	823		2,176
Calculated overflow Jun 30-Jul 2		-71	2,105
Calculated overflow Jul 3-Jul 5		-31	2,074
Calculated overflow Jul 9-11		-29	2,045
Calculated Finish Sep 30/17	1663	-5985	2,045
Actual Finish Sep 30/17			**3,323**
Difference due to "Unknowns"			**1,280** **(Favourable)**
Unknowns			
Leaking through wall		?	
Surface runoff into pond from #3/7	?		
Recharge with groundwater	?		

Recharge from groundwater and surface runoff from #3/#7 - 2017 was a year of close to normal rainfall. We gained a "net" recharge from groundwater and surface runoff from #3/#7 that exceeded any losses to leakage by 1,280,000 igal over the four summer months. It was a year that saw the pond overflow as late as July 11.

2016 was a year with less than half of our normal rainfall. The outflow from #15 went dry in August. The combined inflow from #11, #12, and #6 would not have been more than half that measured in 2017, given a higher proportion would have been absorbed by the dry soil. We are safe in assuming that the "net" recharge from groundwater and surface runoff from #3/7 less losses to leakage would have exceeded 700,000 igal.

In November of 2017, the level of the pond was lowered by nine (and eventually eleven feet to replace the intake screen) to see how the recharge rate might be affected if the pond was dramatically lowered. We were hoping the pond might recover much like a dug well. The "net" recharge was measured on thirteen days and found to average just under 10,000 igal per day. This is consistent with the four-month 2017 total of 1,280,000 igal calculated above. Unfortunately, there is no evidence to suggest that recharge rates would substantially increase if we extracted high volumes of water earlier in the irrigation season in the hope that the pond would quickly recover.

Surface Runoff Area - An analysis of the area draining into the pond was completed by the Committee and concluded that the collection area is approximately twenty-five acres (including the pond and parking lot – see map in Appendix). In the winter of 2017/18, the pond rose from near empty to full between Dec 1 and Feb 20. The surface runoff collected by the pond is very high when turf is frozen (60% of rainfall), and far lower in summer (ballpark 10% of rainfall) when water is absorbed by the turf. The gain of 2,000,000 igal per month in the 2017/18 winter demonstrates that a larger pond could be filled before the irrigation seasons begins.

With the data collected in 2016 and 2017, we can make some educated estimates of the water we can extract from the pond under different rainfall scenarios.

<u>Water Available from Pond at Different Levels of Rainfall</u>

June 1 to September 30
(igal millions)

Rainfall Assumed % Normal	Rainfall Assumed mm	Start June 1	Evaporation Assumed	Direct Rainfall	Parking Lot Runoff	Inflow from #11,6,12	"Net" Recharge #3, 7	Total Available
100%	364	6.37	-0.82	0.87	0.33	0.55	1.30	***8.60***
75%	273	6.37	-0.82	0.65	0.25	0.41	1.00	***7.86***
50%	182	6.37	-0.82	0.44	0.17	0.27	0.70	***7.13***
25%	91	6.37	-0.82	0.28	0.08	0.13	0.35	***6.39***
0%	0	6.37	-0.82	0.00	0.00	0	0	***5.55***

There may be justification for lining the wall of the pond along #9 to minimize leakage and retain the water. Lining the bottom would be counterproductive if the lining prevents the significant inflow of recharge water from the higher water table on #3 and #7.

APPENDIX CONTENTS – ***Current Water Storage***

***GRASS, SOIL, and WATER CAPACITY*:**

Grass: Chester has a collection of grasses common to all courses in northern climates. These are loosely termed "cool season" grasses. It includes Kentucky bluegrass, Poa Annua (Annual bluegrass), Rough bluegrass, Tall fescue, Perennial ryegrass, Creeping bentgrass, and many others. As a group, they need double the water required by the "warm season" grasses found on courses down south. Unfortunately, warm season grasses will not survive up here.

All these "cool season" grasses have different attributes. Most species can develop deep roots (up to 12-18") to harvest moisture if encouraged to, except for Poa Annua whose shallow roots seldom go deeper than 2". Many species can survive a drought if soil moisture doesn't fall below the grass wilting point for too long. If the plant crown has enough moisture, the plant can survive even in a dormant state while it awaits a reviving rain. In drought conditions, Kentucky bluegrass is quick to turn brown yet is resilient and often survives. Poa Annua is not resilient due to its short roots and dies quickly. It also returns quickly because the soil is loaded with the seeds of this prolific seed producer. In our climate, golf courses must live with Poa Annua and therefore manage it as best they can.

All these grasses take their moisture from a root zone extending from the surface to a depth about 1" below the root. That is the target zone for irrigation of grasses. Irrigating anything below that level is out of reach and therefore a waste of water. Roots will reach for moisture slightly below their depth and by keeping the plant a little dry and supplying plentiful oxygen, can be encouraged to go deeper. As the roots grow deeper, the available water increases and allows us to reduce the frequency of irrigation.

Soil: The soil at Chester is classed by the Nova Scotia Soil Survey for Lunenburg County as belonging to three groups – Bridgewater Sandy Loam, Bridgewater Drumlin Loam, and the Riverport Sandy Loam. The Bridgewater soils are not particularly fertile as they are stony, and their rapid drainage leaches out nutrients. The Bridgewater Sandy Loam, our main soil in Chester, is considered "droughty" as it does not retain moisture well. This works to our advantage for drainage and against us for irrigating our turf grasses, where we would like to keep a large reservoir of moisture in the soil to supply our grass. A lower reservoir in the soil translates into a need for more frequent irrigation and less capacity to capture rainfall.

The Riverport soil is also stony with poor fertility. It drains more slowly than the Bridgewater soils which helps with irrigation. This soil can be found on the low areas near and including #14 and #15 where it was mixed during construction with the peat also found there.

Our greens are mostly built with USGA perched water table construction (sand/peat). The exceptions to this are #1, #2, and the left side of #6. These latter three greens are of soil construction. While there are differences in the construction of our greens, these differences can be managed to yield reasonable consistency during play.

As part of this study, fairway soils were sampled to identify their texture classification and thicknesses. Texture determines how good the soils are at holding moisture, while the thickness of the soil layer limits the depth grass roots can go in search of water.

Our Chester soils are predominately Sandy Loam. While some Loam soil can be found on #7, 11, and 13, the rest of our fairways have Sandy Loam over a stony base. The thickness of this soil can be generalized as:

-Thick and stone-free *(6" plus)* to the east of the clubhouse (#1, 2, 3 (to the turn), 7, 8, 9)
-Thin and stony *(stones at 1"-5")* to the north & west of the clubhouse (#4,5,6 and the back nine)

It is evident from our surveys that the length of our grass roots is restricted to a depth where the soil becomes too stony to permit further root development. For the purposes of irrigation planning and determining soil reservoir potential, it is reasonable to generalize that our root zones are 6" on #1,2,3,7,8,9 while on the back nine plus #4, 5, 6, and the last bit of #3 the root zone averages 4".

Water Capacity: The water holding capacity of each soil is determined by the relative percentages of sand (large particles), silt (medium particles), and clay (minute particles). Clay rich soil holds a lot of water and drains slowly. Sand rich soil holds less water and drains rapidly. Our Sandy Loam is predominately sand with enough clay and silt to give us modest water holding capacity and acceptable drainage.

The figure below illustrates how our soil holds water.

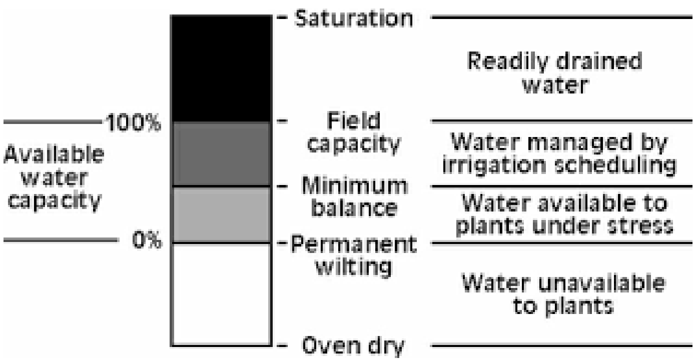


Figure from Plant and Soil Sciences eLibrary.

A typical soil is 50% solids (sand, silt, clay), and 50% voids (to be filled with needed air and water). When rain or irrigation overfills the soil, the spaces between the soil particles become unsustainably filled with water. After one to four days, gravity will have drained the excess water to a sustainable level called ***Field Capacity***. At Chester, our moisture testing pegs this at roughly **28-30%** water (by volume). While this is at the high end for Sandy Loam, the organic content of the soil can drive Field Capacity much higher than normal, as can well aerated soil.

At a far lower level, the ***Permanent Wilting Point*** is a moisture level (**13-15%**) where the adhesion of water to the soil particles is too strong to allow our grass plants to extract any more water. They will go dormant and eventually die without additional water. Some species die slowly, some quickly (Poa Annua).

The difference between Field Capacity (28-30%) and the Permanent Wilting Point (13-15%) is what is available to the roots of our grass plants – ***Plant Available Water*** (**15%**). When the available water is high, our grass will use it liberally; when it is low, the grass will struggle to get water due to the high suction forces that requires. At low levels, the plants will become stressed and use as little as 25% of the water they use when it is readily available.

Irrigation is normally recommended when the Plant Available Water has dropped by 50%. In Chester, that translates to scheduling an ***Irrigation Point*** when soil moisture has dropped to **20-22**%. This is a compromise between the need to encourage roots to grow deeper and a desire to avoid overstressing the plant. It is preferable to irrigate as infrequently as possible and as deeply as possible.

The shallow roots found on our back nine fairways present an irrigation challenge. With a root depth of 4" and a loss of as much as 0.15" per day to evaporation and transpiration (or "evapotranspiration"), one textbook approach would be to irrigate with 0.30" *every second day* during our peak July periods. Fortunately, through *deficit irrigation* we can successfully maintain grass below the highest level of moisture replacement and reduce the amount of water required to irrigate our course. We are not growing a vegetable crop where the product needs to be bigger, brighter, and taller. We are growing grass to an acceptable level of appearance, above its wilting point, that resists traffic and heat stress. Ideally, the grass will be sufficiently hydrated to spread and repair itself. In times of drought, this may not be attainable if water supplies are restricted. During extended dry periods, our focus should be foremost on keeping the plants alive and to a lessor extent, maintaining the green appearance.

We have recently purchased equipment to improve our soils, as follows:

1) AERO-Vator - One of the significant historical challenges to growing good turf at Chester has been soil compaction. Compacted soils do not allow water, oxygen and nutrients to penetrate to the root zone. Water tends to run off before it can be absorbed, so we don't get the maximum benefit from rain or irrigation. Roots are shallower and the water holding capacity of the soil is reduced. Conventional aeration with deep tines has not been possible due to the rocky nature of our soil. The slit aerifier we use is too shallow to alleviate compaction. In June/17, the Club purchased an innovative machine called an AERO-Vator that was used to loosen compacted soil and allow water and air to move downward. All fairways were aerified in July/17. The benefit was immediate. Grass density increased, and good turf developed in places where no turf could be established before.

Bulk density testing values of our fairway soils in late July after treatment with the AERO-Vator ranged from 1.0 to 1.3 - showing a remarkably low level of compaction. By late September the values had risen to 1.3 to 1.6 – far more compacted than July/17. We again used the AERO-Vator in October/17 to reduce compaction to optimal levels. This process must be ongoing if we are to maintain the Field Capacity of our Sandy Loam soil at 28-30% water and foster deeper root growth.

2) TDR Moisture Probe - The Club acquired a TDR Moisture Probe in August/17 so that we can quickly measure moisture levels in greens, tees and fairways. It has been used to identify Field Capacity (28-30%) around the course and to determine what moisture level triggers severe stress (Wilting Point (13-15%)). It has allowed us to learn how quickly our saturated soil drains down to Field Capacity (2-4 days) following a heavy rain. Another significant use was to monitor moisture loss in several test plots and across three fairways and compare these findings to reference measurements posted daily by Environment Canada's station at the Stanfield Airport. Knowing how Chester's measurements compare to the Stanfield Airport allows us to use a reliable public source to help guide our irrigation needs. In 2017, we learned that our turf moisture loss on fairways was running at only 66% of the Stanfield Airport reference data adjusted for turf. This is a result of deliberately giving the turf less than it might like to have (deficit irrigation), which lowers moisture loss, with perhaps a helping assist from our cooler location along the coast. More on this under the "Turf Water Requirements" section.

In the future, the TDR Probe can map fairway moisture on each hole and identify areas that stay wet longer and need less irrigation, as well as the drier areas that need more irrigation. Knowing the personality of each fairway can translate into less water usage. On our greens, the TDR Probe tells us where our irrigation water ends up. This is a far better indicator of distribution uniformity than the conventional method of laying out cans and measuring how much spray falls into each can. The latter tells us where the spray was directed; the TDR tells us where it migrated to in the soil. This is important on a contoured putting green, where high points and slopes might end up with half the intended water.

Some members have asked if we have considered capping our fairways with sand – as many new courses are constructed. Organic matter is either added in during construction or accumulates over time. This allows excellent drainage and acceptable moisture retention. Sand-capped fairways can offer an improved playing surface versus those constructed on marginal soils, but at a significant initial cost. In Chester's case, building sand-capped fairways would mean shutting down holes to allow for construction and grow-in. Sand-capped fairways would also likely *increase* the demand for fairway irrigation water.

*APPENDIX CONTENTS – **Grass, Soil, and Water Capacity***

TURF WATER REQUIREMENTS:

Turf needs water at different levels; a lowest level (C) required for most plants to survive (albeit as brown grass), a higher level (B) to look good (green?), and a yet higher level (A) to flourish and repair itself fully.

The highest level might be described as 100% replacement of any water lost from the root zone through *evaporation* from the soil and *transpiration* from the plant itself. The two combined are called *evapotranspiration* (ET_L).

Evapotranspiration has been tracked since 2012 by Environment Canada at four locations in Nova Scotia. Stanfield International Airport is the location felt to most closely represent Chester. They report a reference crop ET_0 which we can adjust to any crop by the applicable crop factor; for turf (ET_L) we multiply by 90%.

Temperature, direct sunlight, wind, humidity, type of grass turf, along with the availability of moisture are the variables that influence evapotranspiration.

We can be certain the turf is getting enough water if we replace any moisture lost to evapotranspiration. Turf can also withstand some reduction in this level if it is conditioned to do so gradually. This approach to water management is called "Deficit Irrigation" and can yield reductions of 20% or more in water use without sacrificing turf quality.

The areas of the golf course that we are concerned with are:

Green Zones (and surrounds)	326,000 sq ft
Approaches	82,000
Tee Zones & Range	155,000
Fairway Ist Cut	843,000
Adjacent Rough on Fairway System	753,000
Total	**2,159,000 sq ft (or 50 acres)**

To calculate the water required to adequately irrigate 2,159,000 sq ft, we have come up with five methods:

1) The industry rule of thumb of 1" per week used to design our irrigation system
2) The Rain Bird guide "Irrigation Scheduling – Use ET to Save Water"
3) Use Evapotranspiration data to calculate needed moisture replacement
4) Look at past years to see what was sufficient to maintain the course in "adequate" condition
5) Look at 2017 and 2016 by area to see what irrigation is required to achieve our 2017 level

Method 1* - *Industry Rule of Thumb……………………* *Gross Irrigation …..* *19,500,000* *igal

The irrigation season of June 1 to Sep 30 is 17.43 weeks x 1"/week x 2,159,000 sq ft At 6.23 igal/cu ft that works out to 19,540,000 igal. The method tells us the required gross capacity of an irrigation system to provide water when there is no rain, before any deduction is made for irrigation efficiency losses. It implies I"/ week is good enough to cover the hottest periods in the summer, which means it must overstate the requirement in the cooler September period. It seems an ideal tool for system design (its intended use) yet possibly an overly conservative tool for calculating total water requirements for the summer.

Method 2* – *Rain Bird guide ……………………* *Gross Irrigation …..* *19,100,000* *igal

This guide serves to simplify irrigation scheduling which is normally a complex process. It also allows us to estimate total water requirements. The guide omits several relevant considerations such as crop adjustments to reference evapotranspiration, irrigation inefficiencies, and numerous soil factors, and states they largely offset one another.

Like Method 1 above, it is a calculation of how much irrigation is required to replace moisture loss. Rain is not factored into the calculation but would be in the real world by course superintendents. As in Method 1, it may be good tool for scheduling (its intended use) yet is possibly an inappropriate tool for calculating total water requirements for the summer.

Method 3 – Evapotranspiration …………………….

There are some industry people who feel it is necessary to replace all the moisture lost by the turf……………………………………………… **Gross Irrigation** …. *Replace 100%.......* ***23,300,000** igal*

The consensus of many experts is that it is possible to reduce water use by 20% or more if the turf is managed through "Deficit Irrigation"…… *Replace 80% only….* ***18,600,000** igal*

Method 4 – Past Years With Minimal Turf Loss………………………………….. ***14,300,000** igal*

In years where the combined "Effective" Precipitation and Irrigation in Chester exceeded 10,000,000 igal, our turf quality was adequate (and that was before we purchased the AERO-Vator). The "adequate" judgement is highly subjective. It might better be described as "minimal turf loss experienced". It certainly cannot be described as "green", since many of those years would have included periods where the turf went brown in some areas.

This translates to a gross irrigation (before efficiency losses) of 14,300,000 igal. Remember that this figure is the irrigation required to match or exceed "adequate" conditions in prior years, *with no allowance for rainfall*.

Method 5 – Maintain Appearance Achieved in 2017………………………………….. ***16,400,000** igal*

	2016 Moisture Replaced % of ET_L Actual	**2017 Moisture Replaced** % of ET_L Actual	**Target? Moisture Replaced** % of ET_L Actual
Green Zones & Nursery	63%	91%	***80%***
Approaches	57%	76%	***80%***
Tee Zones & Range	68%	87%	***80%***
Fairway Zones	36%	66%	***65%***

This seems the best method to determine how much water is required to duplicate conditions achieved in 2017. Look at 2016 and 2017 to see what irrigation levels worked and where we fell short. We know that our fairways looked good in 2017 with a replacement of only 66% of the Stanfield Airport ET_L. This is supported by the data from our test plots and fairway monitoring, which show a moisture loss in the range of 50% to 75% of the Stanfield Airport ET_L, given current irrigation practices.

With continued prep work with the AERO-Vator, the fairways can be maintained at 65% of the airport ET_L level. We believe the difference is due to the lower temperatures Chester sees near the sea and to our "Deficit Irrigation" practices" – if you give it a bit less, it will use less.

The green zones saw minor turf loss in 2016 with a 63% moisture replacement rate but the 91% rate in 2017 is probably high. The greens were quite soft at times and a water replacement rate of 80% of ET_L is likely adequate while giving more advantage to bent grass and less to Poa Annua.

Tee and approaches are high traffic areas and should be watered at the same rate as the greens. We should experiment with less water on the approaches, as water sprayed on the greens may feed downgrade to the approaches.

Using these replacement rates gives the following Gross Irrigation requirement in 2016 and 2017 if we were to maintain the course to the level achieved in 2017. Note that 2016 is a bit lower due to the evapotranspiration reference data being lower in that year.

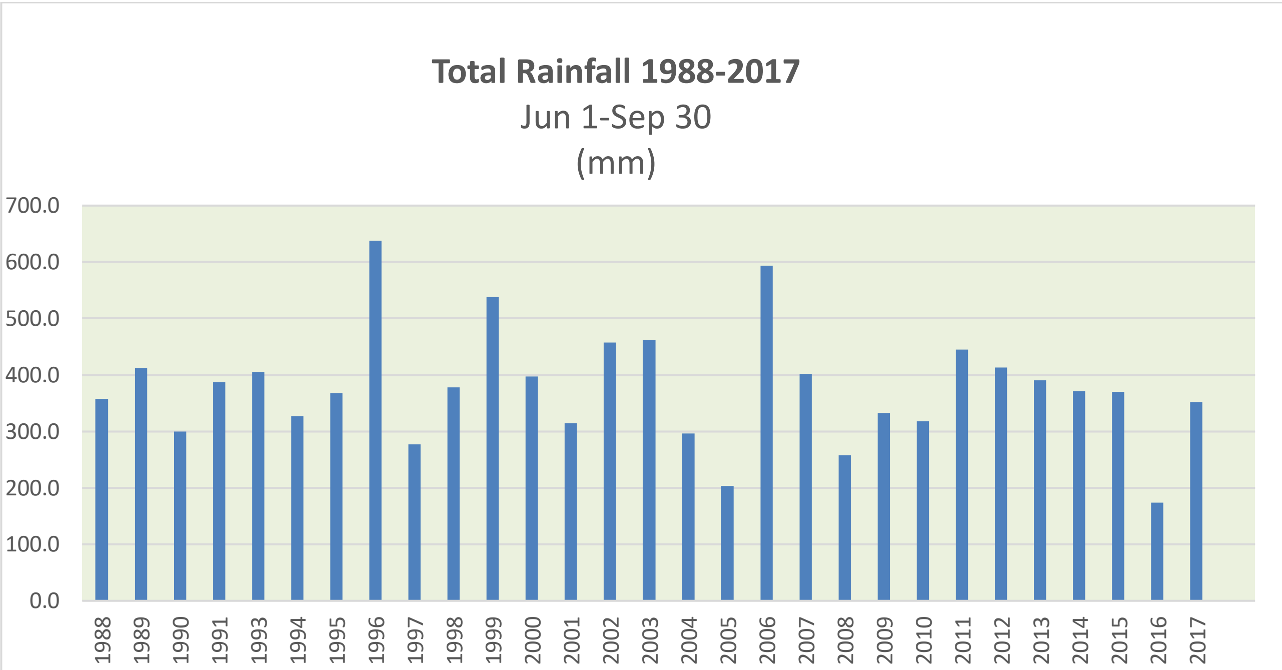
	2016 Gross Irrigation Required (no rain) igal'000	2017 Gross Irrigation Required (no rain) igal'000
Green Zones & Nursery	2,770	2,870
Approaches	697	722
Tee Zones & Range	1,317	1,365
Fairway Zones	11,018	11,418
Hand Water+Wash	83	25
Total (Rounded)	15,900	16,400

*APPENDIX CONTENTS – **Turf Water Requirements***

A) *GENERAL*
B) SIZE OF IRRIGATED AREAS
C) CALCULATIONS OF IRRIGATION REQUIRED
D) MOISTURE REQUIRED IN 2016/2017 TO MAINTAIN AT 2017 LEVELS

PRECIPITATION and IRRIGATION:

We have rainfall records at Chester thanks to our mini weather station near the maintenance building. Our station was calibrated in 2017 and we confirmed that it is still reporting rainfall accurately.



The average rainfall for 2008 to 2017 is 11% below the average from 1988 to 1997. Whether this is statistically significant, given normal swings in rainfall, is up for debate.

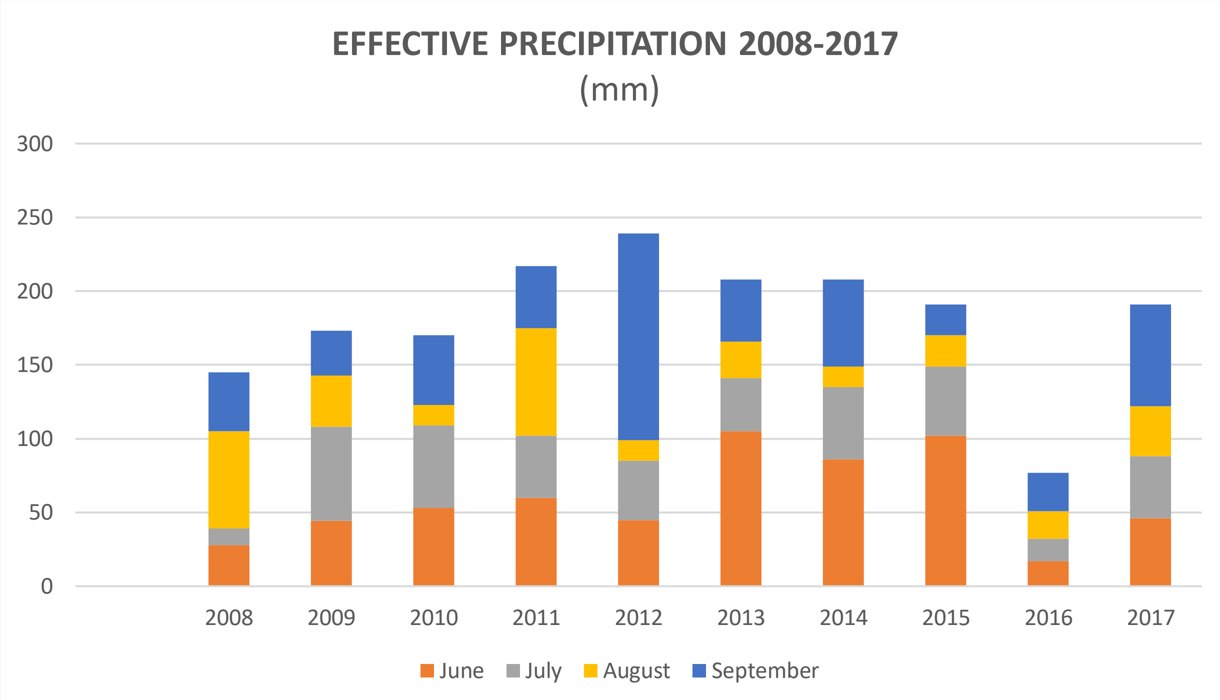
Here is the rainfall record by month since 2000.

(mm)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Avg.	Min.
June	60	110	88	105	68	66	307	94	50	85	101	100	98	180	144	178	38	93	109	38
July	83	90	113	55	88	23	183	116	24	123	100	76	89	82	93	100	40	76	86	23
August	138	50	93	195	80	39	74	117	111	67	35	142	39	43	36	46	44	75	79	35
September	118	65	165	108	61	75	29	75	73	58	82	127	187	85	98	46	52	108	90	29
Total:	398	315	458	463	296	203	593	402	258	333	318	445	413	390	371	370	174	352	364	174

The average total for the four months June to September since 2000 is 364mm (14.3”). The 174mm we received in 2016 was less than half the average – 8,400,000 igal less. The only year close to this dry in the past 29 years was 2005, when we received 203mm.

Our grass sees little benefit if the rainfall event is less than 5mm, as it evaporates before it can soak in (unless the soil is already wet). And 25% of any rainfall over 5mm is unavailable to the root zone as some water goes to runoff or percolates below the root zone. Runoff occurs when rain is falling faster than the soil can absorb it. Deep percolation occurs when soil receives a quantity of water above its storage capacity. Soil has only so much capacity to store water, so any amount above that capacity quickly drains through it due to gravity.

By adjusting daily rainfall for these two factors, it is possible to calculate *Effective Precipitation*, which is simply the amount of rainfall our soil gets to keep. An analysis of daily rainfall over the past ten summers shows Effective Precipitation in Chester averages 53% of Gross Rainfall. In 2016, it was a miserly 44% of Gross Rainfall; in 2017, it was a more favourable 54%.



Our irrigation system is more effective at applying water than rainfall. It has the advantage of being applied at low rates that allow high absorption into the soil, in amounts that will allow it to only go as deep as the roots. Some of the water is lost to wind drift, to evaporation in the air and on the soil, to plant interception, and minor losses to runoff and deep percolation. These losses are about 30% of the total irrigation, leaving *Effective Irrigation* at 70% of the *Gross Irrigation* applied.

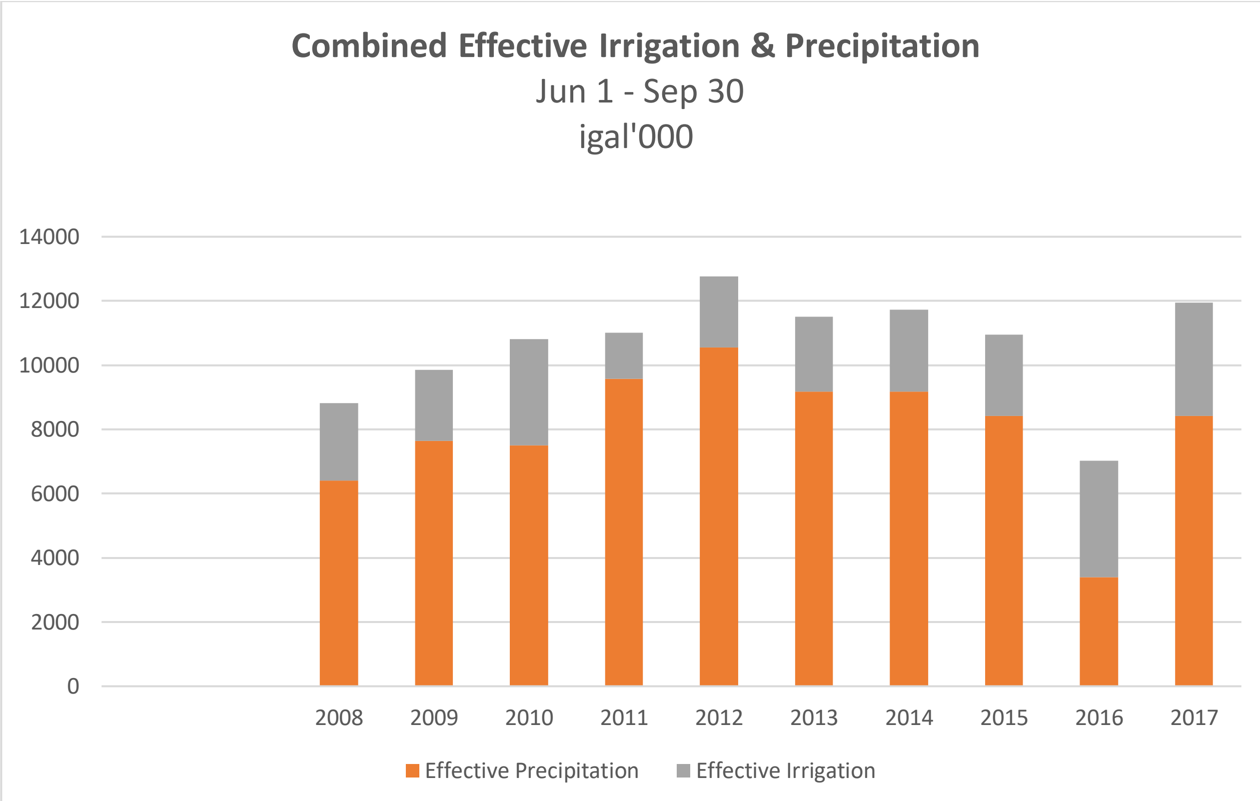
The concept of Effective Irrigation and Rainfall is explained in Irrigation Industry Association of BC: *"Landscape Sprinkler Irrigation Calculator",* available on-line.

Effective Irrigation - Chester GC Pumping Records (igal'000)										
	2008	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***
Gross Irrigation	3,445	3,150	4,724	2,037	3,168	3,338	3,649	3,607	5,171	5,028
Irrigation Efficiency	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Effective Irrigation	**2,412**	**2,205**	**3,307**	**1,426**	**2,217**	**2,337**	**2,554**	**2,525**	**3,620**	**3,519**

(June I to September 30)

By combining the Effective Irrigation and the Effective Precipitation, it is possible to see what level of usable moisture was put into our irrigated areas. In 2016, our 50 irrigated acres received approximately 7,700,000 igal of gross rainfall and 5,200,000 igal of gross irrigation – a combined total of 12,900,000 igal over four months. The "effective" portion of this was 6,900,000 igal. That's what our soil saw.

In 2017, our gross rainfall of 15,500,000 igal was double that of 2016. Our combined gross precipitation and irrigation reached in 2017 was 20,600,000 igal. The "effective" portion of this was just under 12,000,000 igal.



*APPENDIX CONTENTS – **Precipitation & Irrigation***

A) *TOTAL RAINFALL*

A) *TOTAL RAINFALL*

B) *EFFECTIVE PRECIPITATION*

C) *IRRIGATION HISTORY*

D) *EFFECTIVE IRRIGATION*

E) *COMBINED EFFECTIVE PRECIPITATION & IRRIGATION*

F) *RAIN AND POND INFLOW RECORDS*

G) *RAIN GAUGE TESTING*

SHORTFALL:

We can look at the different levels of rainfall and determine what irrigation levels can be buffered by our present pond.

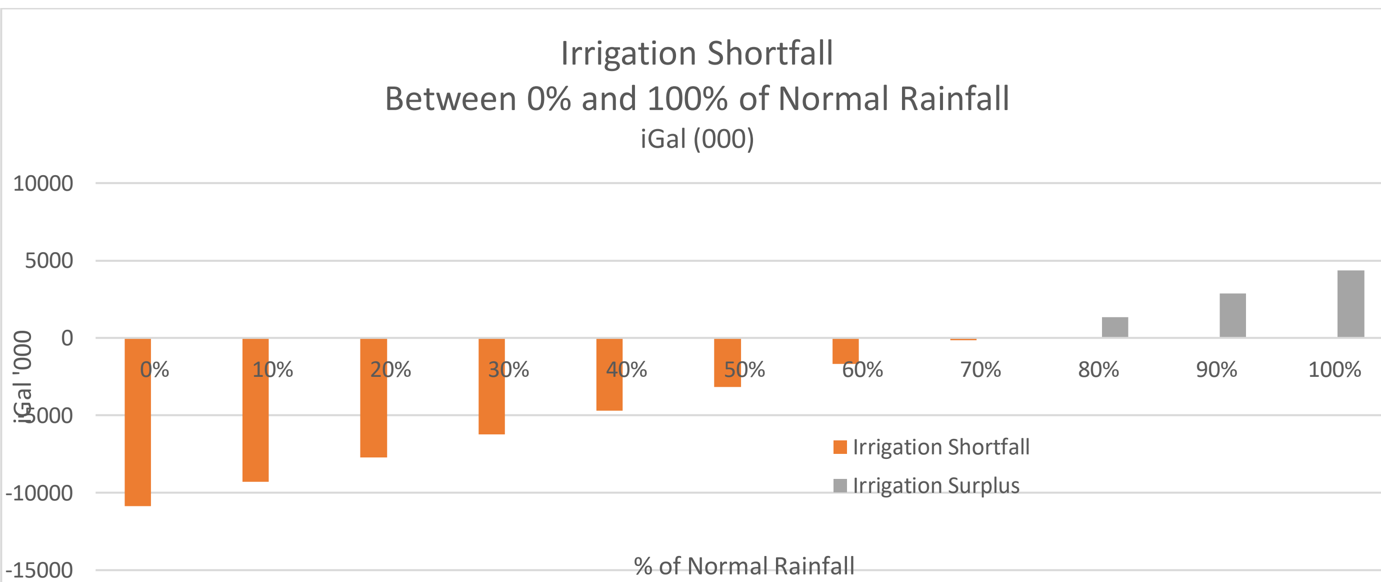
Required to irrigate to 2017 levels – 16,400,000 Igal

We would be OK if we received 72% of our normal rainfall of 364mm, if the rain events were reasonably spaced. The course would remain green throughout most of the year and turf loss would be rare.
Rainfall above 72% of normal has occurred in 26 of the last 29 years (90%).
In a year like 2016, we would need access to another 3,500,000 – 4,000,000 igal (depending on effectiveness).

Required to irrigate to levels with minimal turf loss – 14,300,000 igal

We would be OK if we received 58% of our normal rainfall of 364mm, if the rain events were reasonably spaced. The course would often turn brown during dry stretches, but turf loss would be minimal.
Rainfall above 58% of normal has occurred in 27 of the last 29 years (93%).
In a year like 2016, we would be need access to another 1,400,000 –1,700,000 igal (depending on effectiveness).

Our thinking must also include consideration for a reasonable reserve for greens, tees, and approaches - our most important areas. A reserve was maintained in 2016 in case the next six weeks saw no rain. Ironically, despite the drought that was so evident on our fairways (and some tees), Chester experienced a slightly higher level of play in 2016 than it did in 2017 when conditions were better.



*APPENDIX CONTENTS – **Shortfall***

A) CALCULATION OF SHORTFALL AT DIFFERENT LEVELS OF RAINFALL

OPTIONS FOR NEW CAPACITY:

There are four options that the Committee feels are the most promising. To move forward, we require engineering expertise as well as permitting from NS Environment.

1) ***Adding pond height - $100k***. This gains us 1,450,000 igal if we can add two feet. It modifies an existing storage pond with no impact on neighbours or wetlands. It should be easy to permit. An attractive cost/benefit ratio.
2) ***Deepen the Pond - $325k.*** This gains us 750,000 igal if we go down two feet. It should be easy to permit. <u>Not</u> an attractive cost benefit ratio.
3) ***Dig Well(s) and Transfer to Main Pond -$100k***??* It should be possible to dig a well in the wetland area beside the ditch on #11 near the forward tee. We would then pump water to the pond through the culvert under the parking lot. Gain could be 500,000++ igal per year? In 2017, flow from #10 exceeded 100,000 igal/mo. in Jun, Jul, Sep. Water exiting this area does not cross neighbouring properties, making permitting easier. Wetlands could be an issue, however.
4) ***Dig Pond behind #16, Capture Outflow from #15 - $?*** A new pond behind #16 was ballparked at $55,000 in 2003. That seems low. It could hold 2,000,000 igal but would require the capture of water now exiting the course to adjacent properties. This may make permitting difficult. If a permit could be obtained this could be a good option. Note that the flow out of #15 reached 1,000,000 igal per month in June, July, and September/17. Wetlands could be an issue here as well.

Other options examined but not recommended for further evaluation are as follows:

5) ***Expand the Pond Footprint*** - The most likely area for expansion is towards #8. This would gain us 700,000 igal at considerable costs in excavation and rebuilding the dam. Not an attractive cost benefit ratio. It would also encroach on #8.
6) ***Dig Pond between #14 and #15 -*** A new pond here was considered in 2003 but deemed questionable from an engineering perspective because of the presence of peat. It also would require the capture of water now exiting the course to adjacent properties. It may also be a wetland. Both factors work against permitting. In effect, we can accomplish the same thing behind #16.

APPENDIX CONTENTS – ***Capacity Options***

RECOMMENDATIONS:

1) Maintain the aerification program introduced in 2017 with the new AERO-Vator machine. This provides the maximum capture and storage potential for rainfall and irrigation. It also offers the best opportunity to maximize our root depth and improve plant health and resilience.

2) Continue the practice of doing irrigation audits introduced in 2017. This minimizes the number of problems that impact course conditions.

3) Select an amount to be kept in reserve for greens, tees, and approaches for an extended drought. Six weeks normal hydration for these priority areas would be 1,800,000 igal. Allowing for 7,500 igal/day pond recharge would allow 1,500,000 igal to suffice as a reserve. This reserve can be reduced in September as our main irrigation season closes.

4) Irrigate fairways using our 2017 practice of "deficit irrigation" until our water storage falls to the level of our selected reserve. This will allow our fairways to be in acceptable condition for as long as possible into the playing season. There is always the chance that enough rain will eventually arrive to carry us through the drought.

5) Explore the following possibilities to reduce water consumption below the 16,400,000 igal figure. We need to remember that the 16,400,000 was a level that yielded adequate grass appearance in 2017. It is a sample size of one!! A slightly lower level of fairway hydration might have been OK as well?

   a) Experiment with dialing back the output of spray heads located in the rough on in-line fairway systems
   b) Tailor output of spray heads within each fairway grid to the wetness characteristics of that fairway. Some areas remain far wetter than others. This requires a fairway mapping effort, with software available in conjunction with our TDR Moisture Reader.
   c) Experiment with lower moisture levels on select fairway areas to see how far we can push things before we get into turf loss issues; i.e., how low can the moisture go and how long can the turf remain brown before our dormant grass turns into dead grass?

6) Present the Board and membership with the best options and relevant costs to reduce the chance of major impacts from drought in the coming years. ***Do we wish to spend money examining our options to increase capacity, and capital to implement these options?***