EXECUTIVE SUMMARY

This report represents a brief discussion on several research projects conducted by or with Parjana Distribution in collaboration with various government, private, and educational entities to validate the efficacy of the Parjana Energy-passive Groundwater Recharge Product (EGRP®) system. These individual research projects generated experimental data documenting how the EGRP® system performs in various applications. The overall aim of conducting these research projects is to determine the efficacy of the EGRP® system in eliminating standing surface water without disturbing ecological balance. There are five independent research projects that have been conducted to date that are summarized in this report (Table 1). Overall, findings of these research reports suggest that the EGRP® system successfully reduces standing surface water, significantly increases surface infiltration and does not have an adverse effect on groundwater quality. Additional information and reports to supplement this summary are available upon request.

Table 1: Summary List of Research Investigations and Goals

Belle Isle Shelter 5, Detroit MI

- To determine the efficacy of EGRP® system in reducing standing surface water.
- To determine the efficacy of the EGRP® system in reducing the volume of runoff being delivered to Detroit Water & Sewerage Department as part of combined sewer system.
- To explore the effect of the EGRP® system on groundwater levels and quality.

Coleman A. Young International Airport, Detroit MI

- To evaluate how the EGRP® system enhances surface water infiltration
- To evaluate whether the EGRP® system acts a straight vertical conduit to lower soil layers that might allow surface contaminants to enter shallow groundwater tables

Mettetal Airport, Canton MI

- To determine if the EGRP® system could assist in draining an existing sediment forebay with long-term ponding

Geneva International Airport, Switzerland

- To determine the impact of the EGRP® system on soil moisture distribution and shallow water table response in an area without standing water problems

Edgabston Cricket Club

- To determine the influence of the EGRP® system on the infiltration, surface firmness and soil moisture on an athletic field.

BELLE ISLE SHELTER 5, DETROIT MI

Belle Isle, a 985-acre island in the Detroit River near the mouth of Lake St. Clair, is considered one of the jewels of the city of Detroit. Having recently been leased to The State of Michigan for thirty years, the Department of Natural Resources (DNR) has primary authority over its management within the Michigan State Park system (Greene 2013). The DNR intends to spend up to $20 million for park improvements and infrastructure upgrades to further enhance visitors, experience on the island (Litcherman 2013). The DNR is also looking for opportunities to reduce Belle Isle's $1.55 million annual approximate stormwater fee from Detroit Water and Sewerage District (DWSD). This demonstration project was made possible through a grant from the Michigan Economic Development Corporation (MEDC) and was intended to vastly mitigate or completely eliminate the expense of managing stormwater by DWSD.

Installation on Belle Isle consisted of eleven lines of diamond pattern EGRP® (Figure 2). The location of the EGRP® lines can be seen in Figure 3 along with the overall study design information. Belle Isle consists predominantly of interbedded sands and silty clays to a depth of approximately 20 feet. The potentiometric surface varied from 0.5 to 6 feet below the surface depending on rainfall and piezometric well location (ECT 2016).

Figure 1: Test area (Shelter 5) on Belle Isle.

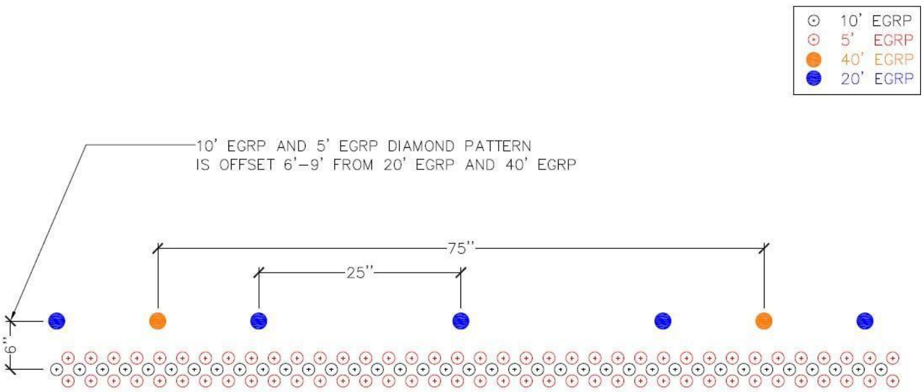

Figure 2: Configuration of EGRP® diamond pattern

Figure 3: Locations of EGRP® lines on Belle Isle (ECT 2016)

The primary goals of this investigation were to determine if the EGRP® system could eliminate standing water on an approximately 24 acre parcel and decrease the volume of stormwater delivered to DWSD through the municipal combined sewer drain system thereby alleviating the cost associated with treatment.

A secondary goal was to explore the effect the EGRP® system has on groundwater.

Results:

Figure 4 and 5 represent total cumulative in-pipe flow from test site before and after installation. Both figures are separated into three distinct time periods (Pre-Installation, Post-Installation, and Performance) with the cumulative flow and precipitation initialized to zero at the beginning of each time period for ease of interpretation. These figures graphically depict the main findings of the investigation which include (ECT2016):

- Prior to installation, the amount of runoff volume was nearly double the amount of rainfall volume due to the pipe network capturing water from a larger area of the island and possibly influenced by the Detroit River.
- After installation, the runoff volume is much less than rainfall volume.
- The rainfall has less direct impact on the amount of runoff from the site when comparing control site versus test site.
- There was an 80% reduction in the total amount of runoff volume from the test site.

In addition to in-pipe flow monitoring, groundwater elevation monitoring was conducted in 10 minute intervals at five monitoring well locations (Figure 6). Results suggest no effect on the local groundwater elevation related to the presence of EGRP®s with groundwater elevation fluctuating similarly in response to rain events on both the test and control sites (ECT 2016). Finally, on October 10, 2014 groundwater was collected from locations both in the control and test sites and measured for total phosphorus, chloride, total dissolved solids, and E. coli and there was no discernable difference between the two locations (ECT 2016). While no definitive conclusions can be made from a single data point, it is encouraging that there was no measured detrimental effects to groundwater quality post installation.

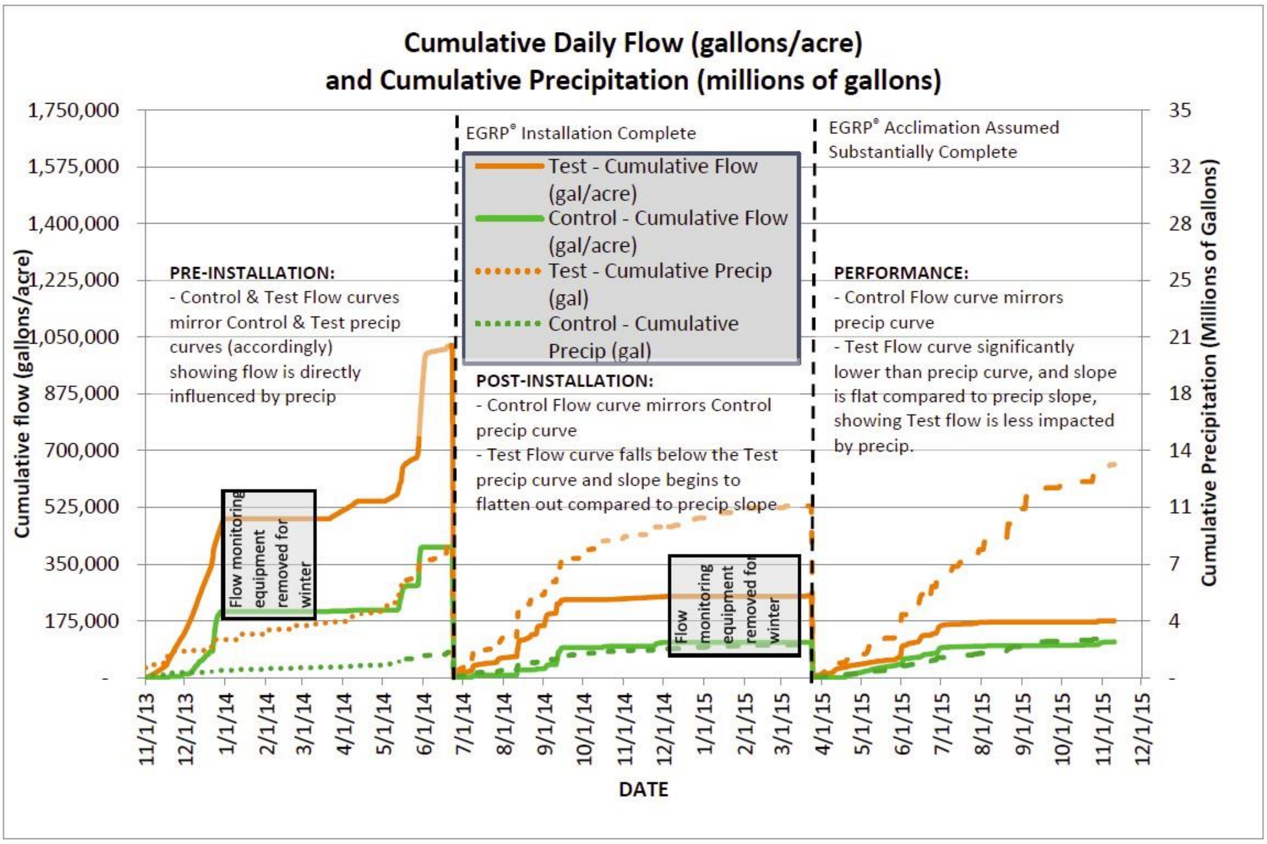

Figure 4: Cumulative daily flow and precipitation during study investigation (ECT 2016).

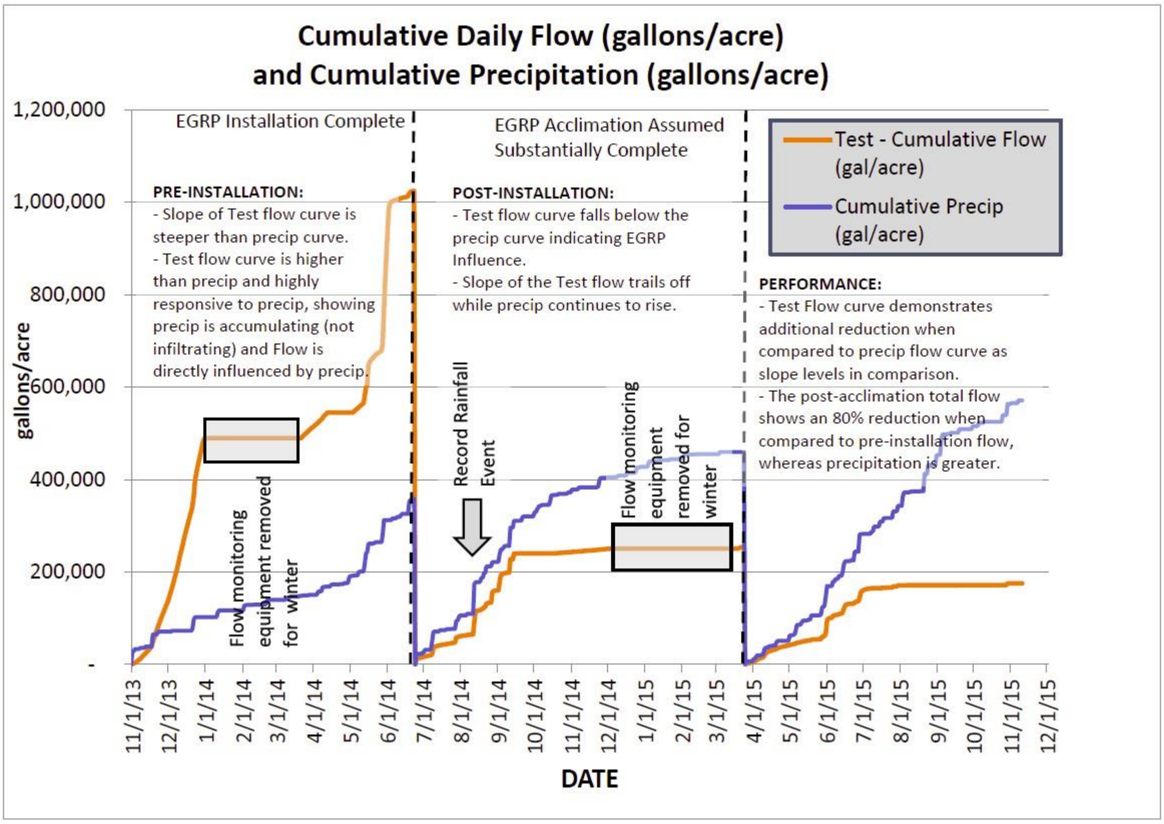

Figure 5: Cumulative daily flow and precipitation for test site during study investigation (ECT 2016).

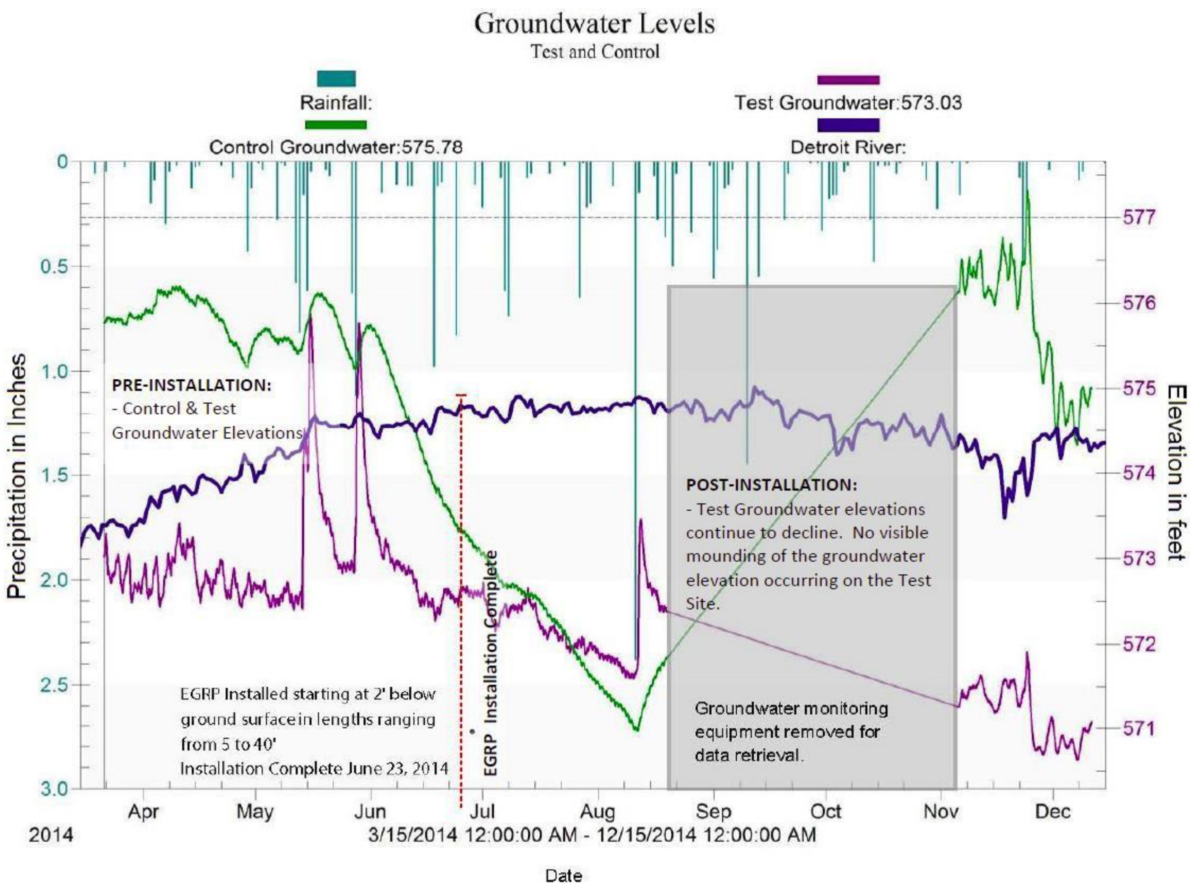

Figure 6: Groundwater and Detroit River water levels during investigation (ECT 2016)

Coleman A. Young International Airport, Detroit MI

This test site is located in the south west corner of the Coleman A. Young International Airport in Detroit, Michigan (Figure 6). This project was developed to address to the concerns of the Michigan Department of Environmental Quality (MDEQ) in regards to the EGRP® system's influence on the infiltration of surface water and its potential to accelerate surface water contaminates into the groundwater supply. The project was under the supervision of the MDEQ and conducted by Dr. David Lusch from Michigan State University (MSU) with consultation from Dr. Donald Carpenter from Lawrence Technological University (LTU). The testing involved the launching of a bromide slug into an infiltration pond where EGRP®s were installed. After the slug was launched a continuous water level of 6” was kept on the pond to simulate a “worst case” scenario of long-term ponding of storm water runoff.

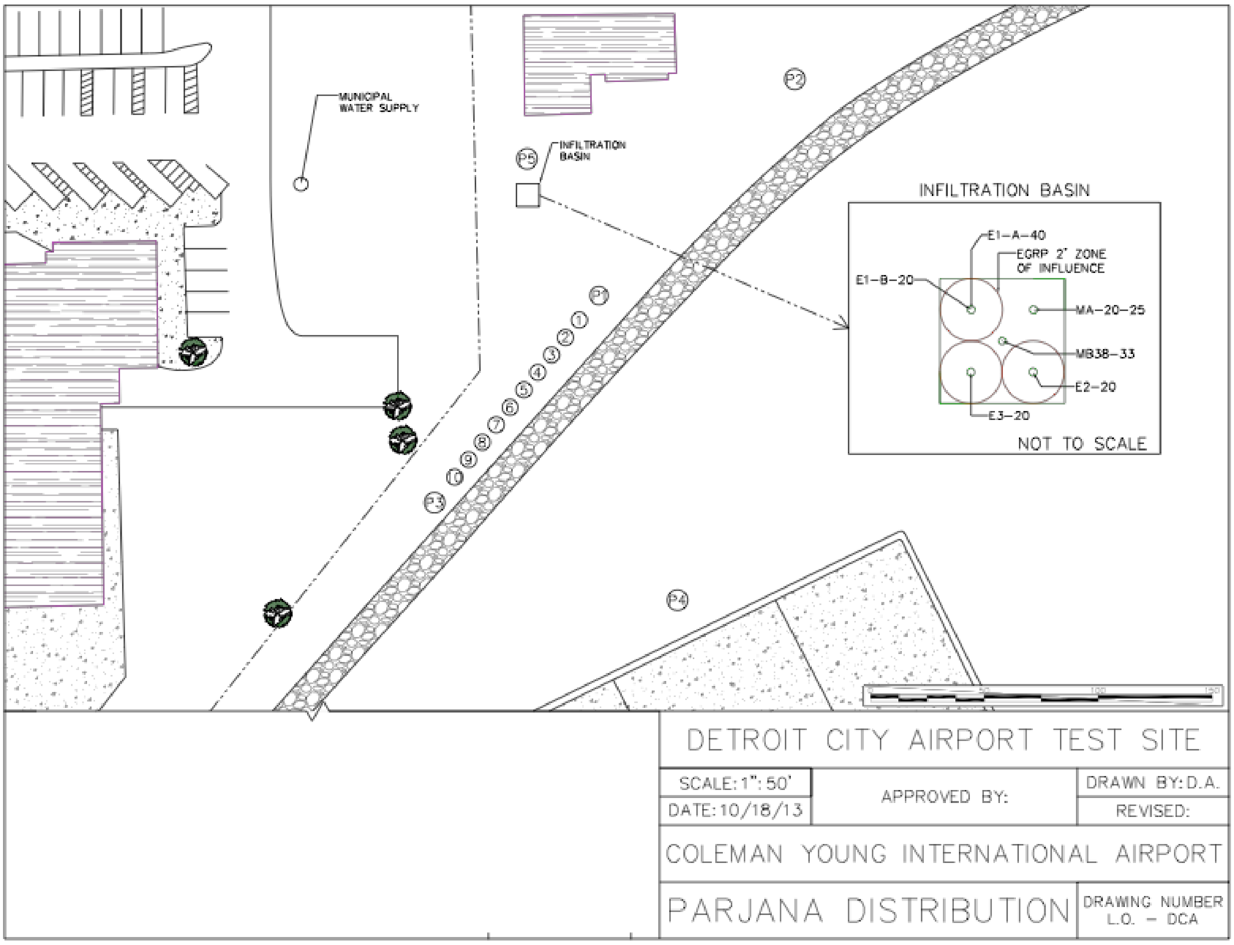

Figure 6: Site Layout for Coleman A. Young Infiltration Study

Table 3: Description of Monitoring Wells and EGRP®s show above in Figure 6

EGRP® AND MONITORING WELL DESCRIPTIONS

Sampling Well Name	Depth	Screen Interval	Description
MA-20-25	27.3'	25'-20'	1" Ground water monitoring well located in EGRP® infiltration basin
MB-38-33	38'	38'-33'	1" Monitoring well located in EGRP® infiltration basin
E1A-40	40'	40'	A 40' EGRP® device installed with a 40' ground water sampling tube
E1B-20	20'	20'	A sampling tube installed 20' below grade on the 40' EGRP® device
E2-20	20'	20'	20' triple EGRP® device installed with sampling tube 4" below grade
E3-20	22'	20'	20' triple EGRP® device installed with sampling tube 2' below grade
P1	22.55'	20'-15'	1" Ground water monitoring well located Southeast and downstream of infiltration basin
P2	40'	38'-33'	1" Ground water monitoring well located Northeast and upstream of infiltration basin
P3	27.5'	25'-20'	1" Ground water monitoring well located Southwest and downstream of infiltration basin
P4	40.8'	39'-34'	1" Ground water monitoring well located South and downstream of infiltration basin
P5	31.1'	29'-24'	1" Ground water monitoring well located North and upstream of infiltration basin

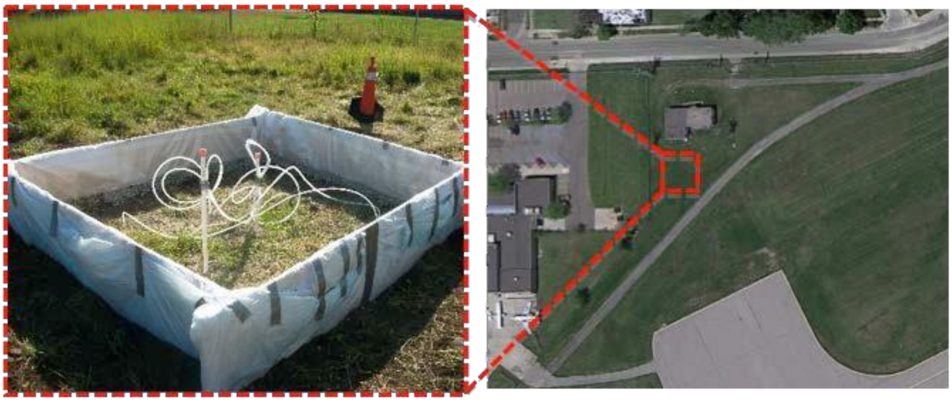

Figure 7: Aerial view of testing site at Coleman A. Young International Airport, Detroit, MI

Results:

Data showed that the EGRP® increased the infiltration rate of surface water 7 to 10 times the rate of native soil conditions (Lusch 2015). However, bromide concentrations were not detected at the bottom of the EGRP® installations until between 16 (E2-20) and 68 days (E3-20) after the slug test was administered. As such, the study also concluded that EGRP®s do not act as vertical drains or injection wells that allow water, along with its' constituents, to flow straight down to the bottom of the EGRP® systems (Lusch 2015).

Geneva International Airport, Switzerland

Parjana EGRP® system was installed at Geneva International Airport (GIA) in late 2012 and was constantly monitored through piezometric testing for nearly two year (GADZ 2014). The goal for GIA was to reduce or eliminate water seepage into underground concrete chambers that are common at the airport; especially chambers that are remote from existing stormwater sewer systems. The research goal is to compare the effects of EGRP® device on shallow water tables and soil moisture distribution. Unlike other typical EGRP® installations, this location had no issues with standing surface water.

Geotechnique Appliquee Deriaz SA (GADZ) compared piezometric water levels between two different zones - one with and one without the EGRP® (Figure 8 and 9). The top soil layers were primarily silt and silty fine sands and were found to have low permeability. The deeper soil layer consisted of a well stratified preconsolidated sandy loam (glacial Moraine) with higher vertical permeability and significantly higher horizontal permeability (10 to 100 times greater) (PCS 2014). The 40 ft deep EGRP® installations on the four corners, and some of the shallower EGRP® installations, penetrate the deeper Moraine soils (Figure 10) (GADZ 2014).

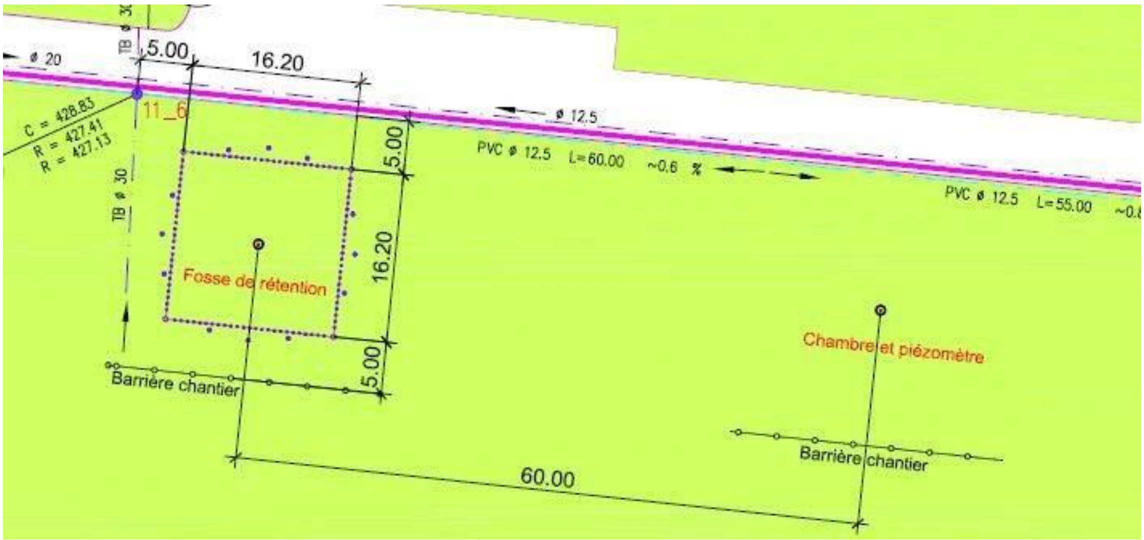

Figure 8: Test study layout adjacent to taxiway at GIA (GADZ 2014).

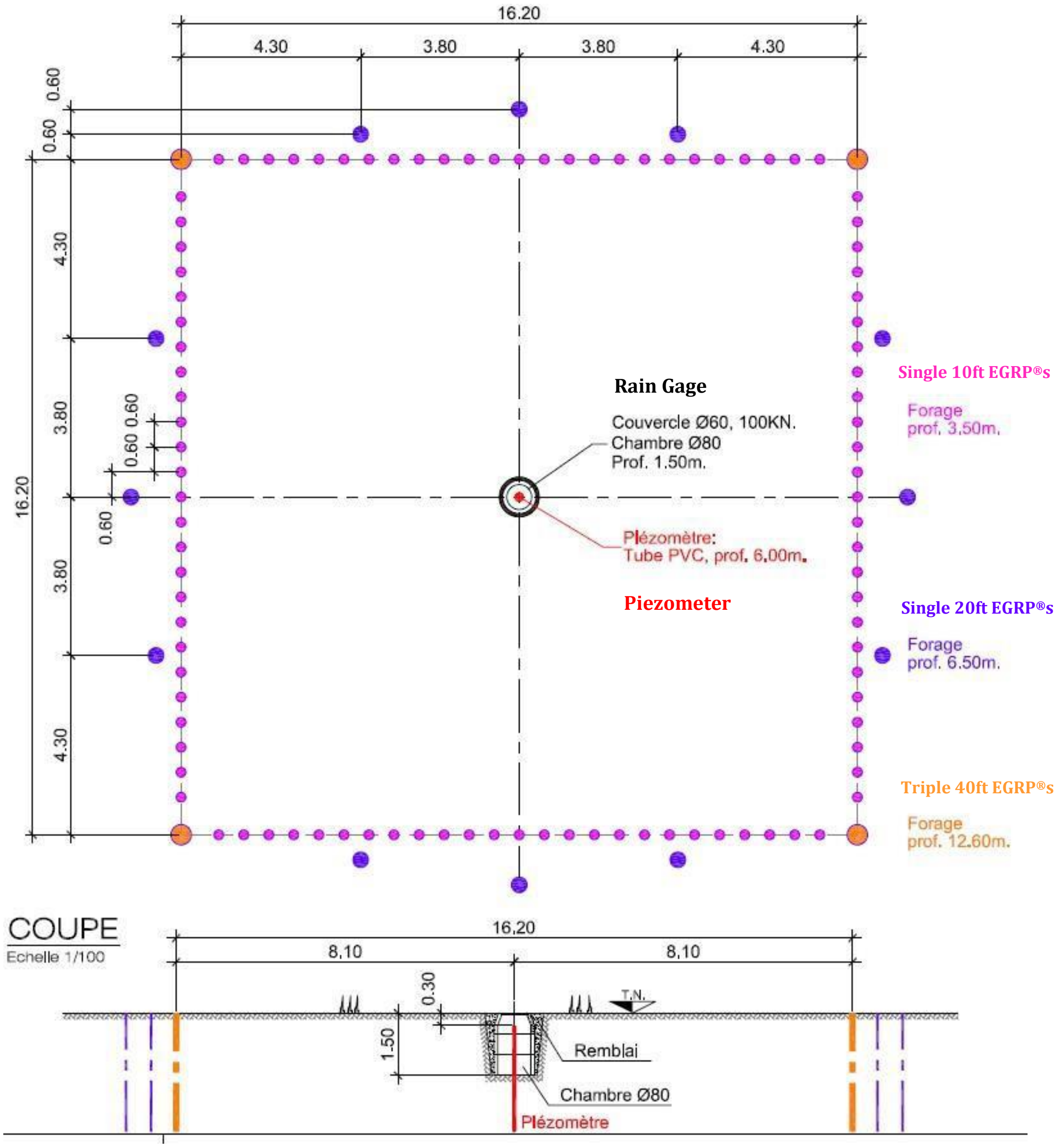

Figure 9: Layout of EGRP® system at GIA (GADZ 2014).

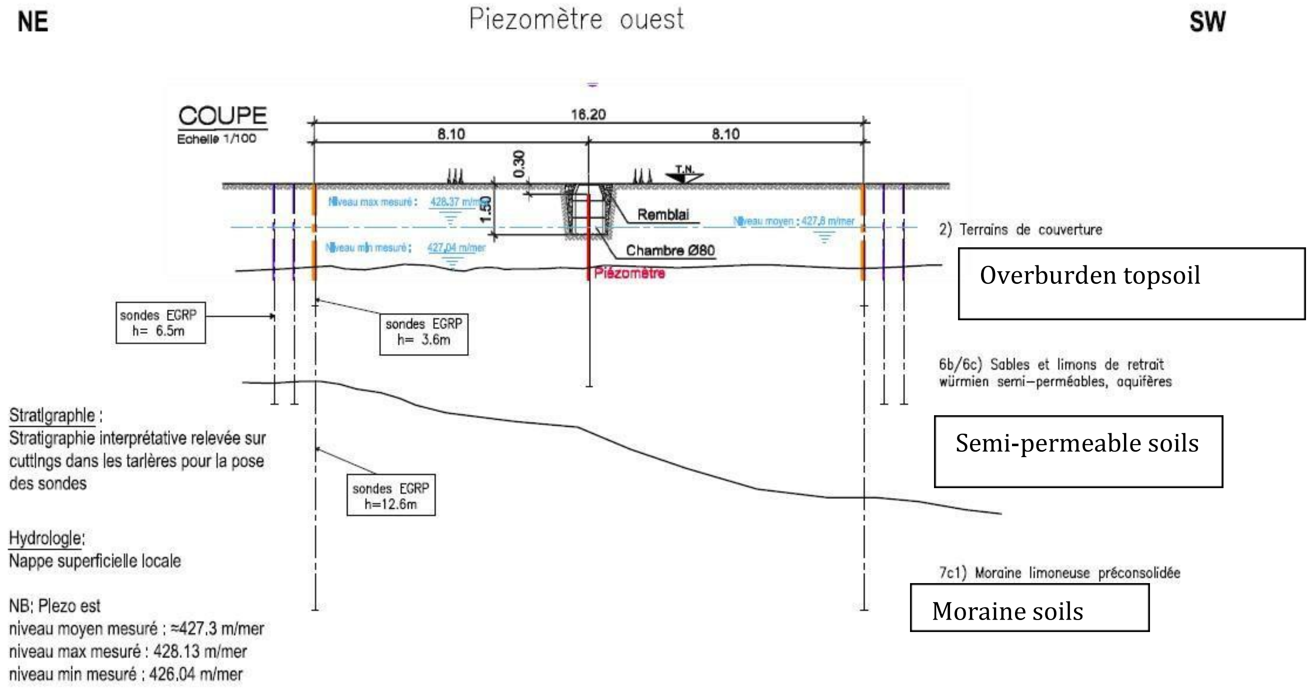

Figure 10: Cross-section of EGRP® installation through stratified soils (GADZ 2014).

Results:

Initial results (PCS 2014) concluded that the level of water table reacts immediately in both zones during "extended" (over 24 consecutive hours) and "intense" (over 0.4 inch) rainfall periods. However, the impact of those rainfall events on increasing the water table level is clearly less in the EGRP® zone (average of 73% less). Likewise the lowering of the water table level after a rainfall event is often clearly less in the EGRP® zone. An example of this is visible in Figure 11 which presents the results of three months of testing (January to March) (GADZ 2014). The report also indicated the water table was higher in the area of the EGRP® system during dry periods. GADZ attributed this to the fact the EGRP® "worked to maintain a degree of saturation as constant as possible in the soil" and the EGRP® system is moving water vertically in both directions thereby creating communication between the surficial layers of topsoil and the permeable to semi-permeable soils beneath (PCS 2014).

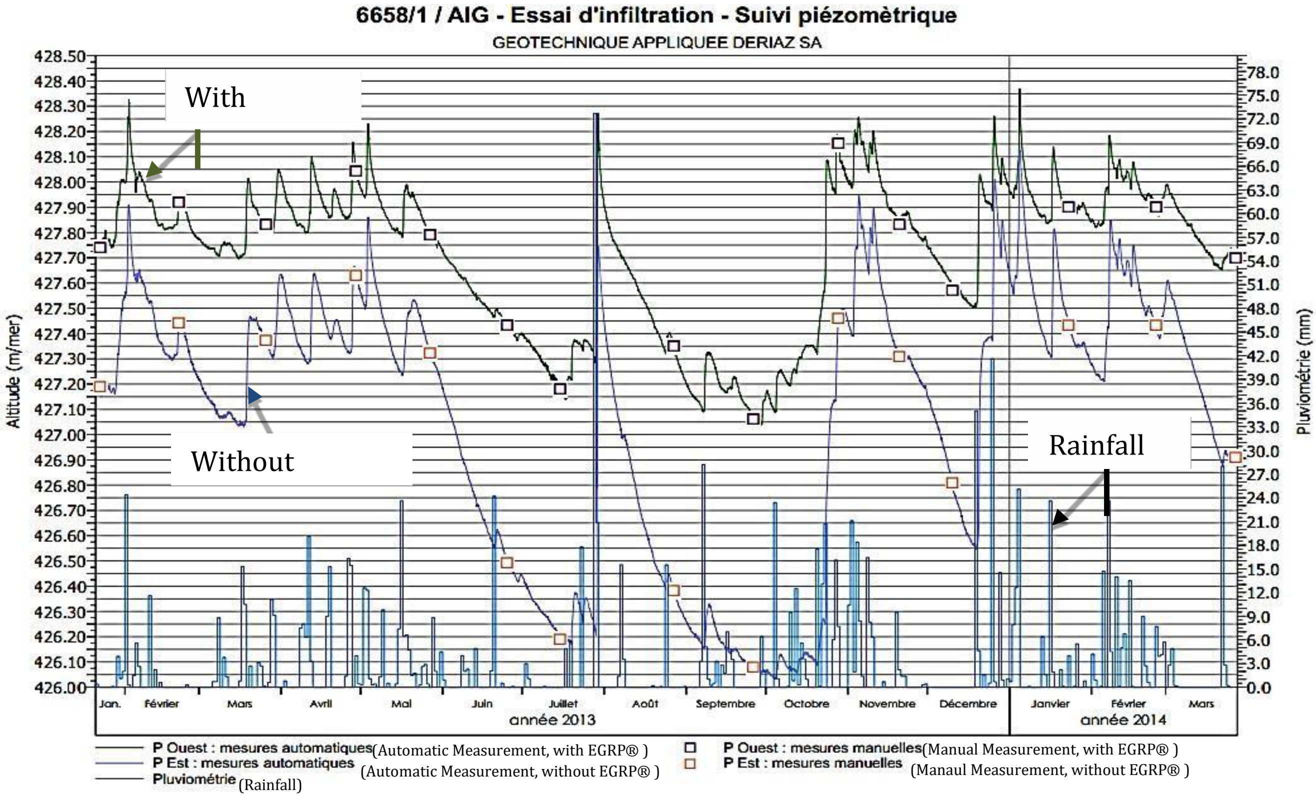

Figure 11: Comparison plot of variation of groundwater levels along with rainfall over period of time at the locations with and without EGRP®, installed at Geneva airport (GADZ 2014)[1].

[1] Original figure in French - groundwater elevation is on left axis and rainfall on right axis

Mettetal Airport, Canton MI

The site is located in the south-west corner of the Mettetal Airport in Canton, Michigan. Figure 12 shows the geographical location of the testing site in relation to the rest of the airport property and the layout of EGRP® installed around forebay. The test site consisted of an initial forebay where water flows and infiltrates into the larger detention pond. The forebay was originally designed for a ½–inch rain event. When there is a rain event above ½-inch or multiple rain events in a row, the water overflows and is released into the detention pond without filtration. Prior to the installation, the forebay did not adequately drain.

The testing was conducted by Mannik & Smith Group, Inc. (MSG 2015). The investigation included tracking water levels in the sediment forebay and four close proximity monitoring wells (Figure 13). The purpose of the investigation was to determine if the EGRP® system would reduce surface water in the forebay and eliminate water within 72 hours following a 1” rain event.

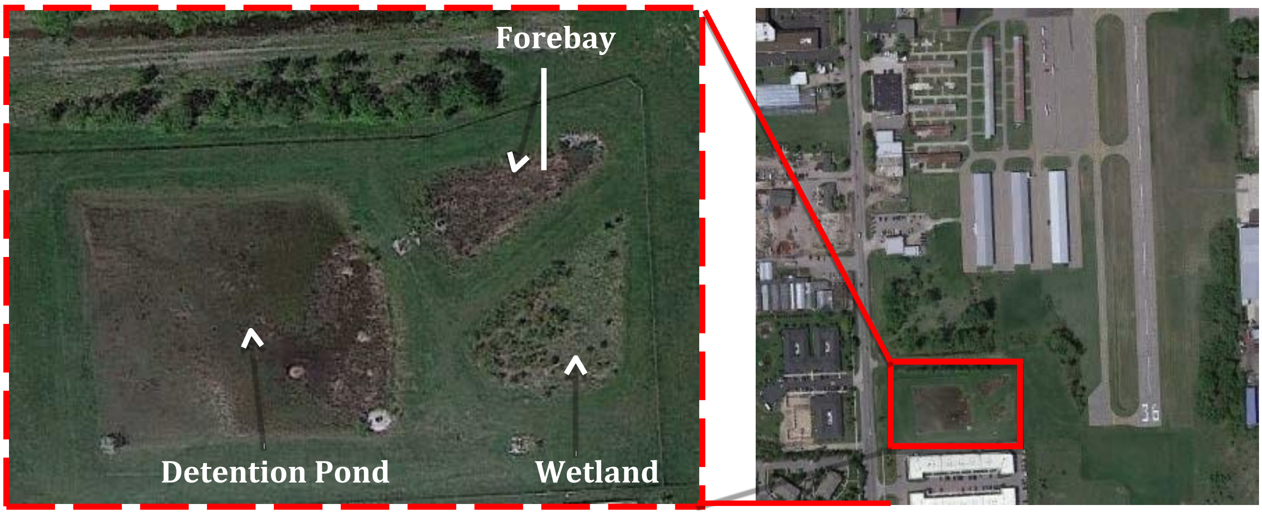

Figure 12 Geographical location and layout of Mettetal airport showing position of installed EGRP® System.

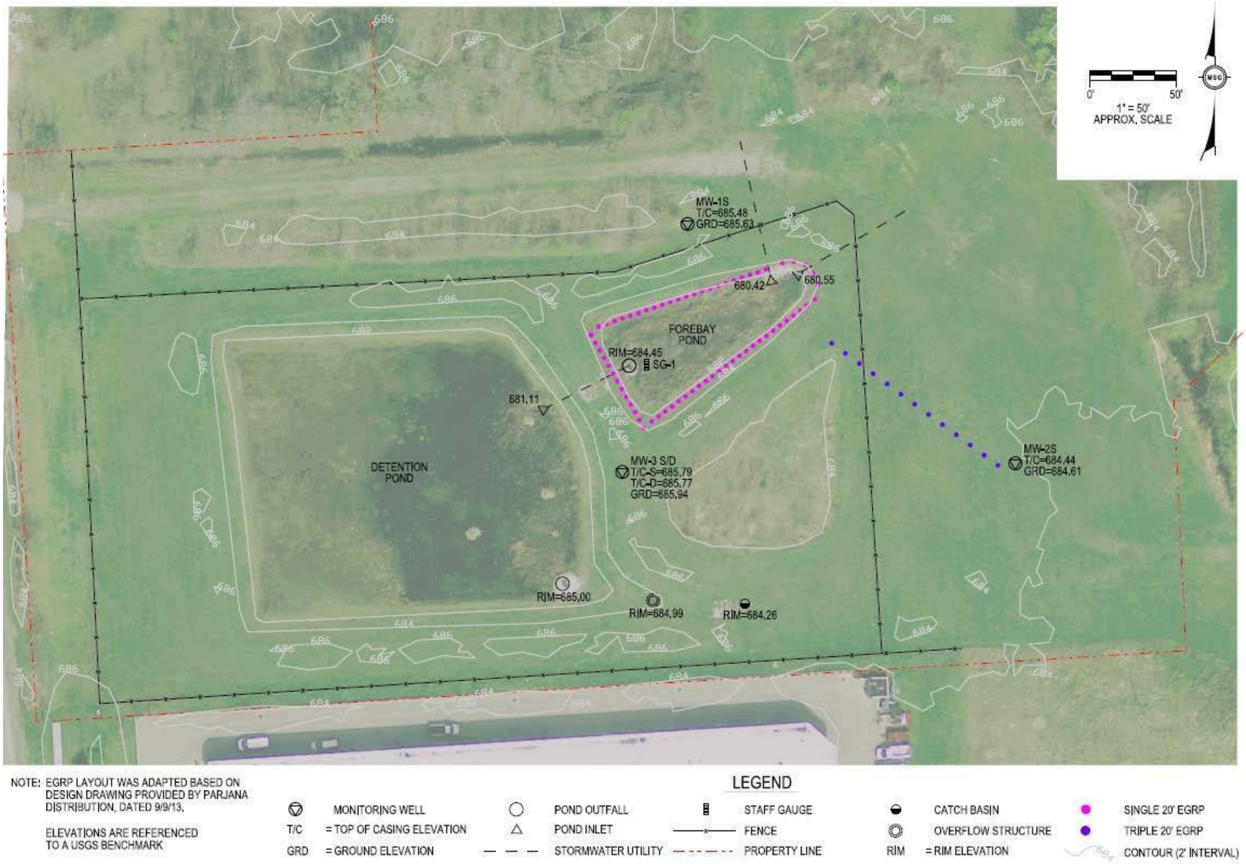

Figure 13: Layout of EGRP® system installed and location of monitoring wells (MSG 2015).

Results:

Figure 14 shows the water level decreasing to previous levels less than 72 hours after a 1" rainfall, which was the goal of the EGRP® system for this project. However, lack of pre- installation data and inconsistencies in variables during the course of the investigation means that MSG is unable to confirm the influence of the EGRP® system on improving infiltration (MSG 2015). MSG did determine that water levels in the shallow monitoring wells mimic the water levels in the forebay closely and are shown to be influenced by rainfall events almost immediately. This indicates good hydrologic connection between the forebay and shallow monitoring wells. Water levels in the deep monitoring well (located in underlying class soils) do not exhibit the same fluctuations and there appears to be no significant hydrologic connection
(MSG 2015).

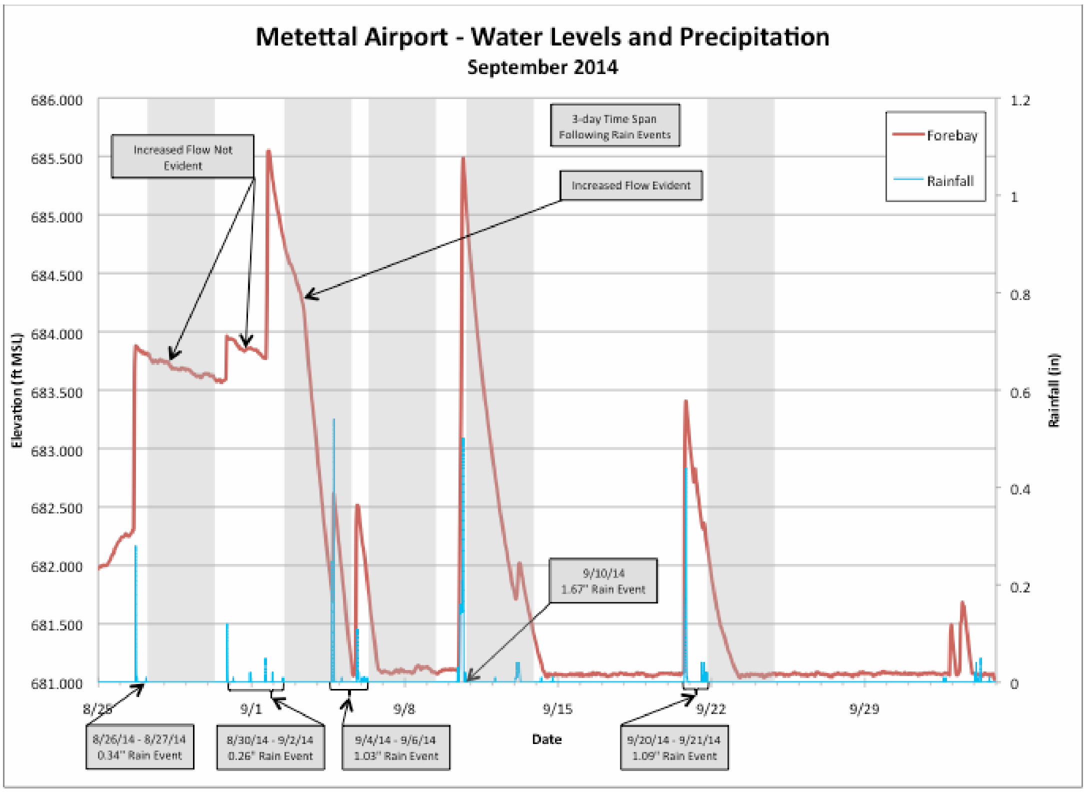

Figure 14: Metettal Airport water levels in response to precipitation (MSG 2015).

Edgbaston County Cricket Club Practice Area, Birmingham, UK

The Edgbaston County Cricket Club (Club) had an EGRP® system installed by Groundwater Dynamics in May of 2013 (GDL 2013) to improve drainage on a practice area that was known for standing water (Figure 15).

The overall soil profile was deemed of poor texture with high silt and clay content and compacted by use (Woodham 2014). STRI Ltd was commissioned by the Club to undertake an independent assessment of the practice area for infiltration, surface firmness, and soil moisture and how they might relate to the installation of the EGRP® system (Woodham 2014).

Results:

STRI Ltd found increased infiltration in areas that were previously deemed unusable for play by the Club (Woodham 2014) which is shown in Figure 16. They also reported that the turf health was in good health for the time of year (May) and that given recent inclement weather "the playing surface was relatively firm and dry (Woodham 2014)." They concluded that the drainage infiltration rates "are more promising and higher than could have been expected given the nature of the site" and were likely contributable to the EGRP® system (Woodham 2014). However, they are unable to confirm these results because there was no testing performed prior to installation. Finally, they conclude that surface firmness and moisture content do not appear to be correlated with the location of the EGRP® system and that excess moisture retention is more likely the result of "excess thatch and compaction" (Woodham 2014).

Figure 15 : Edgbaston Cricket Ground practice field in Birmingham, England in March 13, 2014 at 5pm.

Figure 16 :Edgbaston Cricket Ground practice field in Birmingham, England on March, 14 2014 at 9 am.

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