ASSESSMENT OF SURFACE INLETS PERFORMANCE ON SEDIMENT TRANSPORT TO SUBSURFACE DRAINAGE SYSTEM

S. Li, R. Bhattarai, R. A. Cooke, T. Rendall, V. Dahal, P. K. Kalita

ABSTRACT. *Infield ponding can have detrimental effects on crops and soils and result in reduced yields and increased sedimentation. Surface inlets are commonly used to prevent or reduce incidents of ponding. In this study, the flow and sediment transport characteristics of four surface inlets–the standard Hickenbottom inlet, two inlets (standard and QuickDrain®) designed by Ag-Solutions, and an inlet developed by AgriDrain–were evaluated in both laboratory and field settings with simulation rainfall. The Hickenbottom and QuickDrain® Ag-solutions inlet had higher sediment concentration and sediment load compared to the other inlets. The average sediment concentration and sediment load for Hickenbottom and QuickDrain® Ag-solutions inlets were measured to be 3532.70 mg/L, 64919.05 mg/min, and 3104.31 mg/L, 24880.69 mg/min, respectively. The measured sediment concentration and sediment load for standard Ag-solutions inlet were smaller than Hickenbottom and QuickDrain® Ag-solutions inlets but higher than the AgriDrain inlet. The AgriDrain inlet was the most effective among the four inlets in reducing sediment (66% concentration and 23.2% load compared to Hickenbottom) (p<0.01), but it removed water at a much lower rate compared to other inlets. Additional research is recommended to determine how contaminants like nitrate, phosphorus, and pesticides are transported through these inlets.*

Keywords. *Nonpoint pollution control, Sediment control, Surface inlet.*

Although subsurface (tile) drainage lowers the water table and provides a suitable environment for root growth in the subsoil which increases land productivity (Fraser and Fleming, 2001), it is not uncommon for ponding to occur in depressions of drained fields. During large rainfall events, the water table can rise above the surface in low-lying regions of closed depressions, or areas with low percolation rates within a field. Since some closed depressions are considered more productive farmland because of long-term organic matter and nutrient accumulation (Smith and Livingston, 2013), additional drainage of closed depressions for the purpose of increased crop production can be beneficial. This supplementary drainage can be accomplished through the use of surface inlets or tile risers which are placed at the lowest points in depressions, and connected directly to subsurface tile drainage lines (Ayars and Evans, 2015). However, surface inlets that are directly connected to tile drainage systems can also provide uninterrupted pathways for the movement of sediment to surface waters (Smith et al., 2008). King et al. (2015) reviewed several surface inlet studies and emphasized that traditional surface inlets had the potential to transport pollutants into water bodies.

Based on the function and appearance, there are four main types of surface inlets widely applied in the subsurface drainage system. They are (a) perforated pipe risers, (b) open inlets, (c) rock inlets, and (d) blind inlets. The perforated pipe riser is a cylinder tube with open holes around it. The open inlet is a pipe that is flush with the ground surface. The rock inlet is a sloping perforated pipe buried in the trench then covered by gravel. The blind inlet is more like a filter bed with grading gravel in a low point of depression to minimize the sediment. Tomer et al. (2010) reported that 15% of the flow in a watershed in Iowa was the result of discharge from tile risers. Ginting et al. (2000) indicated that surface inlets transported more than 5% of annual precipitation into the subsurface drainage, resulting in up to 138 kg/ha total solids lost from 1995 to 1998 in a Southern Minnesota River basin. Other studies reported that excessive sediment and nutrients transported into the surface waters of Lake Erie cost $143 million in federal funding for remediation and management oversight (Forster and Rausch, 2002; Richards et al., 2002). On the other hand, Smith et al. (2015) compared tile riser with blind inlet and showed that there was no significant difference in median phosphorus concentration between tile riser (0.37 mg/L) and blind inlet (0.30 mg/L) ($p = 0.59$) in a 10-year study. Feyereisen et al. (2015) reported that gravel or blind inlets produced, on average, 26 kg/ha less total suspended solids (TSS) than open inlets based on a three-year study in Minnesota. Gonzalez et al. (2016) also

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found that blind inlets were an effective alternative to reduce the transport of pollutants, reducing transport by 57%, 58%, 53%, and 11% for atrazine, 2,4-D, metolachlor, and glyphosate, respectively. The Minnesota Agricultural BMP handbook recommended that rock inlets, rather than perforated tile risers, be the preferred choice for farmland (Miller et al., 2012). But both blind and rock inlets are more expensive than a tile riser and require more maintenance. For the blind inlet, sediment trapped needs to be removed regularly resulting in greater labor cost than a tile riser.

Several new types of surface inlets have been developed over the past several years, but their performance has not been evaluated in terms of water and sediment conveyance. The objective of this study was to test three such inlets to characterize their flow capacities and to determine if they were more effective in reducing sediment transport compared to a standard Hickenbottom® inlet. The result of this study is applicable to watersheds where sediment losses from agriculture is a primary source of water pollution and for the agricultural landscape with closed depressions.

Materials and Methods

The study was conducted with the standard Hickenbottom® inlet and three new inlets which have never been evaluated in laboratory or field settings before. Both laboratory and field experiments were conducted with 15 cm (6 in.) inlets (fig. 1). The details on physical dimensions of the inlets used are provided in table 1. All inlets were produced from UV stabilized polypropylene resin.

Figure 1. Surface inlets evaluated in this study. From left to right: (1) Ag-Solutions® QuickDrain® low profile inlet, (2) AgriDrain® wick inlet, (3) Hickenbottom® standard inlet, and (4) Ag-Solutions® standard inlet.

Laboratory Experiments

A series of laboratory experiments were conducted to characterize the flow capacity of these inlets. The system used to measure the flow rate through the inlets consisted of a pump, a structure with a v-notch weir, and a test chamber that emptied into a weigh tank (fig. 2). Water was pumped through the v-notch weir before it entered the test chamber. After passing through the inlet, the water was channeled into the weigh tank. The weir and the weigh tank provided two independent measures of flow rate.

The flow rate (cm^3/s) was determined by measuring the weight of water entering the weigh tank per unit time. For each corresponding flow rate, the ponding depth or height of water on the outside of the surface inlet was recorded. This relationship, known as a rating curve, determines the flow rate of the water based on the ponding depth outside the surface inlet. As the flow rate changed, the water level surrounding structure would be altered. Once the flow stabilized, the corresponding ponding depth was recorded. The flow rate was varied in the range of 0.1 to 7.4 L/min. These procedures were conducted in triplicate for each surface inlet, and the average value was used to develop the rating curve. The same experiment was repeated with the addition of wheat straw to simulate field debris and trash. For each trial, 1.7 kg of dry wheat straw was added around the inlet.

Field Experiments

An experimental research site, consisting of depression with eight receptacles for surface inlets was established at the South Farm Agricultural Experimental Station of the University of Illinois. The depression area was 4 m wide and 6.1 m long. The receptacles were 0.5 m apart on a central

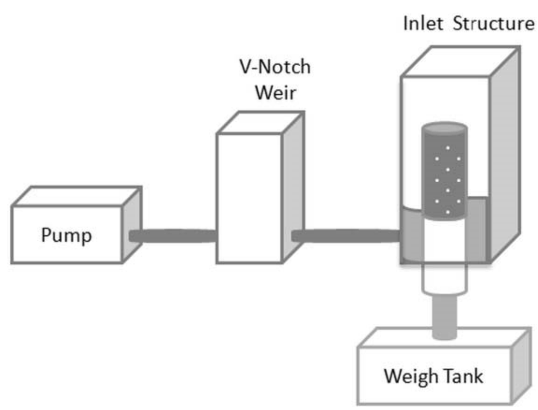

Figure 2. Schematic demonstrating set up for the laboratory test of inlets.

Table 1. Physical parameters for each inlet.

	Ag-Solutions® QuickDrain® Inlet (QD)	AgriDrain® Wick Inlet (AD)	Hickenbottom® Standard Inlet (HB)	Ag-Solutions® Standard Inlet (AS)
Inlet size (cm)	15.24	15.24	15.24	15.24
Overall height (cm)	50.8	45.72	91.44	80
Outside diameter of body (cm)	45.72	15.24	15.24	17.53
Open area (total) (m^2)	0.056		0.051	0.084
Flow equation (cm^3/s)	$y=28.5(x+4.13)^2$ -669.46	$y=12589.11$ $-4582589.11(1+e^{(x+110.2)/18.96})$	$y = 778.71x^2 + 4799.7x$ $- 2038.8$	$y=48.42(x+11.71)^2$ -10916.25

axis parallel to the length, at the lowest section of the depression. Both sides had a 5% slope down to the central axis. A laser level was used to grade the ground with uniform slope, both along the width and along the length, to try to ensure uniform ponding around the surface inlets. Each receptacle was connected to an Agridrain control structure with a v-notch weir, in which flow could be measured and samples collected. A schematic showing plan and side views of the test area is presented in figure 3.

The test area was overlain by a rainfall simulator, consisting of 20 equally spaced Senninger i-wob® #26 (low-angle, 6-groove) nozzles (fig. 4). This nozzle can create large droplets and substantial erosion. The working pressure of this simulator was 0.083 Mpa, and the experiments were conducted at a rainfall intensity of 118.5 mm/h for a 30-min duration, which represents a 75-year return period event for Urbana, Illinois.

The distribution pattern for one nozzle was used to determine the optimum sprinkler layout for highest distribution efficiency (fig. 5a). The highest theoretical distribution efficiency was achieved with the nozzles spaced 1.52 m along the length and 1.34 m along the width in laboratory condition. The resulting theoretical distribution efficiency was 80.4%, which exceeds the 75% criteria for rainfall simulators (Iserloh et al., 2012). The rainfall distribution during field experiment is shown in figure 5b. In this instance, the actual distribution efficiency was 75.6%. Actual distribution efficiency is typically lower than theoretical distribution efficiency because of factors such as the wind and variations in nozzle performance under the experimental condition.

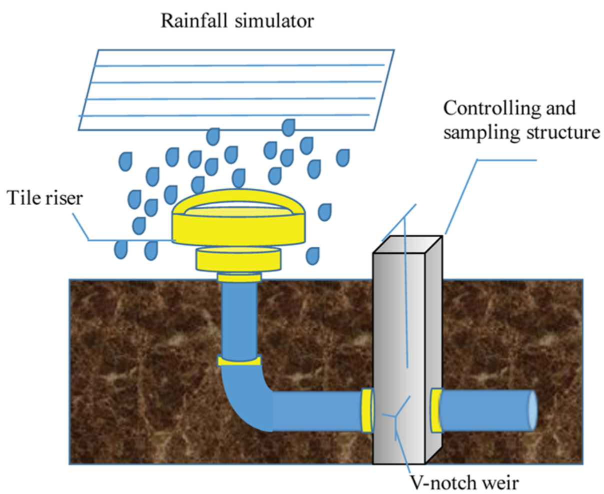

Figure 3. Schematic of field test site.

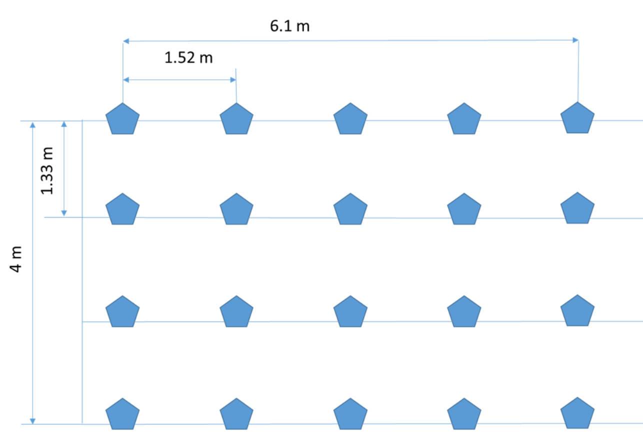

Figure 4. The layout of nozzles in rainfall simulator.

Field Inlet Evaluation

Water was pumped from a nearby pond to the rainfall simulator. Water flowing through the surface inlets was channeled into AgriDrain structures with v-notch weirs, where flow rate was recorded, and samples were extracted to determine sediment concentrations. Eight experimental runs were conducted to evaluate the performance of each inlet. The status and positions of the inlets before each run is summarized in table 2. The first three runs (runs 1, 2, 3 which is also denoted as series 1) had the same inlet position, and all the inlet was cleaned before each run to avoid sediment accumulation. This test series was aimed to evaluate the short-term performance of each inlet. For the runs 3, 4, and 5 (denoted as series 2) and 6, 7, and 8 (denoted as series 3), the position of inlets were altered, and the inlets were only cleaned at the beginning of run 3 and run 6. The test series 2 (runs 3, 4, and 5) and 3 (runs 6, 7, and 8) were designed to evaluate the long-term performance of inlets. The results from series 2 tests were compared with series 3 results to neutralize the inlet position bias. The test site was regraded, and the structures were flushed out with clean water to remove the sediment deposited until there is no visible sediment, between the runs.

Each simulated rainfall event lasted for approximately 30 min after water started flowing over the v-notch in one of the structures. Flow depth was recorded at 2-min intervals, and water samples were collected in glass bottles at 10-min intervals to measure the sediment concentration.

Sediment concentrations were determined by weighing the sample bottles before sample collection (W1), after the water samples were collected (W2), and after the samples were oven dried at approximately 105°C for 48 to 72 h (W3). The concentration of sediment can be calculated by:

$$C_s = \frac{W2 - W1}{\dfrac{W3 - W1}{\rho_s} + \dfrac{W2 - W3}{\rho_w}} \tag{1}$$

where

C_s = sediment concentration,

ρ_s = density of sediment (2.65 g/cm^3),

ρ_w = density of water (1 g/cm^3).

Statistical Method

Two-way ANOVA and box plots were used to compare and illustrate the difference in the sediment concentration and sediment loading rate for each inlet.

1. *Two-way ANOVA*

   The primary purpose of a two-way ANOVA analysis is to understand if there is any interaction between the two independent variables on the dependent variable. The two-way ANOVA is an appropriate method for a

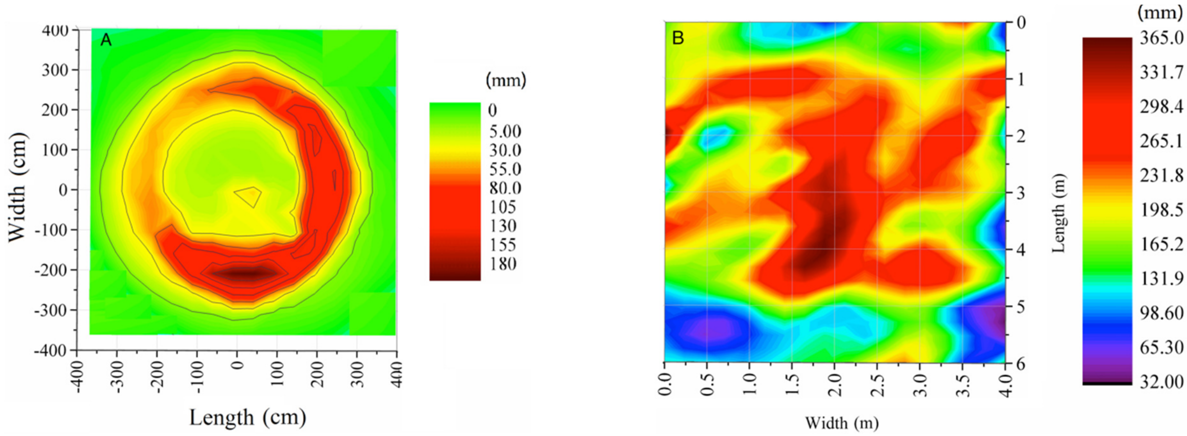

Figure 5. Rainfall distribution of a single nozzle (A) and simulation event (B).

Table 2. The setting of test site and inlet.

Run	Test Site Regraded	Inlet Cleaned at Start of Run	Relative Position of Inlets (Left to Right)[a]
1	Yes	Yes	QD AD HB AS
2	Yes	Yes	QD AD HB AS
3	Yes	Yes	QD AD HB AS
4	Yes	No	QD AD HB AS
5	Yes	No	QD AD HB AS
6	Yes	Yes	HB QD AS AD
7	Yes	No	HB QD AS AD
8	Yes	No	HB QD AS AD

[a] QD-QuickDrain low profile inlet, AD-AgriDrain wick inlet, HB-Hickenbottom standard inlet, and AS-Ag-Solutions standard inlet

study with a quantitative outcome and two categorical explanatory variables. The assumptions of normality, equal variance, and independent errors apply. The method compares the mean differences between groups that have been split on two independent variables (called factors). In this study, the ANOVA analysis was conducted using SPSS® software (IBM Analytics, New York).

2. *Box Plot*

   Box Plot is a convenient way of graphically depicting groups of numerical data through their quartiles. Box plots may also have lines extending vertically from the boxes (whiskers) indicating variability outside the upper and lower quartiles, hence the plot is also called box-and-whisker plot or box-and-whisker diagram. Outliers may be plotted as individual points. Box plots are non-parametric since they display variation in samples of a statistical population without making any assumptions about the underlying statistical distribution. The spacing between the different parts of the box indicate the degree of dispersion (spread) and skewness in the data and show outliers. In addition to the points themselves, box plots allow one to visually estimate interquartile range, mid-hinge, range, mid-range, and mean. In this study, multiple box plots of sediment concentration and load were compared in grouped box plots. Additionally, the data points and the distribution of data were also presented along with the corresponding box plot.

Result and Discussion

Laboratory Test

The relationships between flow rate and ponding depth for each inlet for "debris free" and "with debris" conditions are shown in figure 6. Under debris-free conditions, the standard AS inlet had the highest flow rate for a given ponding depth. There was very little difference in the flow rates of the other three inlets up to a ponding depth of approximately 15 cm. At higher ponding depths (>15 cm), the QD inlet had a higher flow rate than the HB and AD inlets, while the AD inlet had the smallest flow rate among the inlets for a given ponded depth.

When straw was introduced into the test chamber to simulate field debris, the standard AS inlet still had the highest flow rate for a given ponding depth. There was no appreciable difference between the QD and the HB inlets at all ponded depths. Once again, the performance of the AD inlet was similar to that of the QD and HB inlets for ponding depths up to 15 cm. At higher ponding depths (>15 cm), AD inlet had a lower flow than QD and HB inlets for all the ponding depths tested. The HB inlet was the least affected by the addition of debris into the test chamber, with only an approximate 2% average reduction in flow rate. The QD inlet was the most affected by debris, with a 35% average reduction in performance. The remaining two inlets, the standard AS and HB inlets, had similar reductions in flow 22% and 24%, respectively.

Under debris-free conditions, the inlets are best fitted with quadratic rating curves, with the exception of the AD inlet, which is best represented by an S-curve. As shown in table 1, the flow equation for AD inlet is exponential relationship while the relationship is quadratic for other three inlets. It is also likely that all the rating curves are S-shaped, but under the range of ponding depths tested, the inflection point was only reached for the AD inlet. The reason for this phenomenon is the unique design of AD inlet since it is shorter than other three inlets. When the water level rises, the open area of AD inlet can be fully submerged, and the rating curve can reach the inflexion point. In the presence of debris, the rating curves for all the inlets looked to be S-curves. This result indicated that the debris in water reshaped

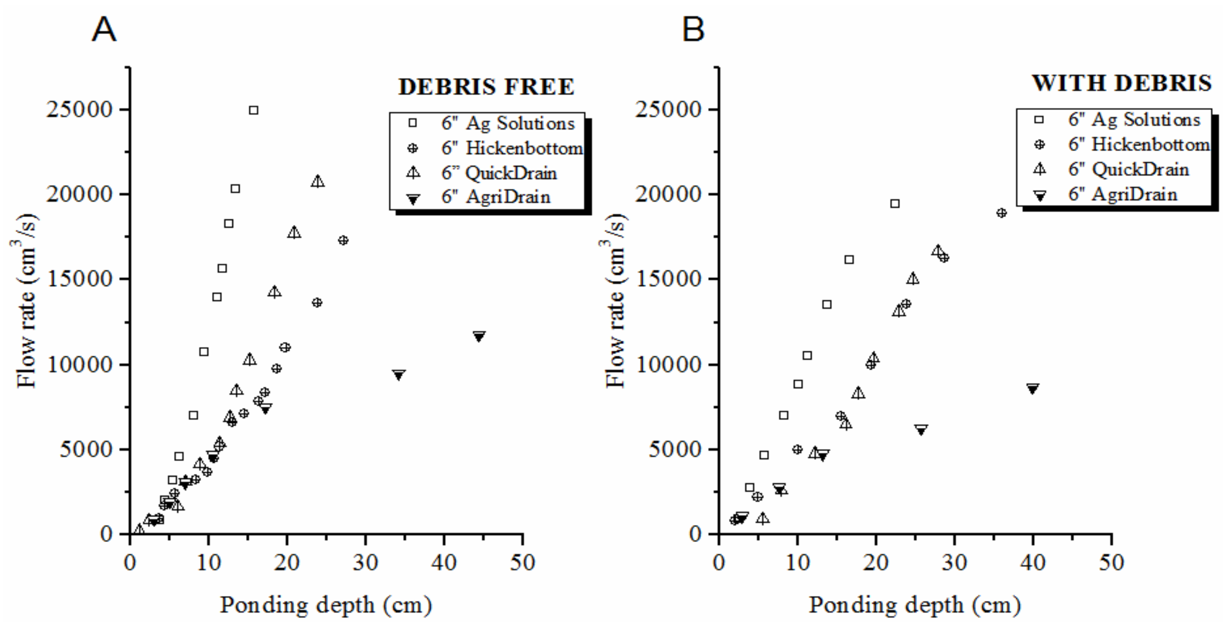

Figure 6. The ponding depth and flow rate relationship for different inlets during the debris free (A) and debris present (B) laboratory test.

the performance of inlet. This also indicates that the flow equations (mostly quadratic) developed for these inlets are no longer valid when they are used under debris condition. The flow equations need to be modified to represent the actual performance of these inlets under debris condition. In this study, wheat straw was used as a surrogate for debris because it is easily available. There are many other kinds of debris like corn stalks, cobs, husks, soybean residue, etc., commonly found in Midwest farmland. Because of the variability in their size, the performance of inlets will vary under various debris from different crop systems. Further studies are needed to study the performance of these inlets under different debris.

Field Test

A series of field tests were conducted to evaluate the inlet performance (both short-term and long-term) in terms of sediment transport. The results of these tests are provided below.

Inlet Short Term Performance Test

Box charts with the analysis of sediment concentration in water samples from each inlet for the first three runs are shown in figure 7. These three runs (runs 1, 2, and 3) are considered together because the inlets were kept in the same position, and were cleaned at the beginning of each run. In run 1, the standard AS inlet had the largest fluctuation in sediment concentration. The highest and lowest sediment concentrations for this structure were 6414 and 1791 mg/L, respectively. The mean sediment concentration for this inlet in run 1 was much higher than those for runs 2 and 3, which may be an indication that the highest value in run 1 was an outlier. If this point is removed, the mean concentration of the inlet in run 1 becomes 3483 mg/L, which is closer to the mean concentrations in run 2 (2703 mg/L) and run 3 (2515 mg/L). The sediment concentrations from the HB and QD inlets remained relatively high and consistent for all

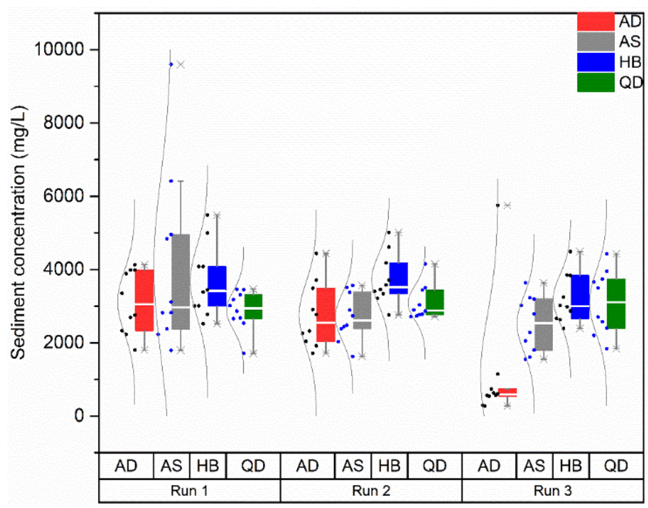

Figure 7. Grouped box chart of sediment concentration during the first three runs. (dot near box is the sediment concentration data for each inlet; the curve line is the distribution of the data; QD-QuickDrain low profile inlet, AD-AgriDrain wick inlet, HB-Hickenbottom standard inlet, and AS-Ag-Solutions standard inlet).

three runs. However, the sediment concentration from the AD inlet varied widely over the three runs with the concentration in the run 3 being extremely low, likely because large soil particles and debris filtered the water as it passed through.

The results of two-way ANOVA analysis of the first three runs are presented in table 3. As indicated in the table, the interaction effect between run and inlet was statistically significant ($p < 0.01$), and there were significant differences in inlets performance ($p < 0.01$). In the multiple comparisons of inlet result, the average sediment concentration from the AD inlet was 2326 mg/L. The average sediment concentrations for AS, QD, and HB were 3104.31, 3243.66, and 3532.70 mg/L, respectively, which were significantly differ-

Table 3. Tests of between-subject effects and multiple comparisons result for sediment concentration in test series 1.

Between-subject Effects					Multiple Comparisons of Inlet					Multiple Comparisons of Test			
								Subset (mean)					
Source	df	Mean Square	F	Sig.	Method	Inlet[a]	N	1	2	Method	Run	N	Subset (mean)
Series 1	2	6367726.209	3.73	0.027		AD	30	2326.43			3	40	2645.1
Inlet	3	7969824.148	4.67	0.004		AS	30		3104.31		2	40	3067.61
Series 1 inlet	6	5143272.828	3.01	0.009	S-N-K	QD	30		3243.66	S-N-K	1	40	3442.61
Error	108	1707698.583				HB	30		3532.70				
Total	120					Sig.		1	0.42		Sig.		0.15

[a] QD-QuickDrain low profile inlet, AD-AgriDrain wick inlet, HB-Hickenbottom standard inlet, and AS-Ag-Solutions standard inlet

ent from AD inlet (p <0.01). These results indicate that different inlets could produce variations in sediment concentration. The comparisons of test result showed there was no significant different between each run mean concentration (p = 0.15). This result suggested that the inlets performances were not impacted by the setting.

Box charts of the load result for the first three runs (runs 1, 2, and 3) are shown in figure 8. From the mean sediment load showed in box chart, in all three runs, the AD inlet delivered the lowest load. The QD inlet had the second lowest load in the first run, but the standard AS inlet had the second lowest load in the second and third runs. The HB inlet transported the highest amount of sediment in all three runs. The standard AS inlet was the most consistent across runs. Those result indicated that the mean sediment loads were significantly different for each inlet in each run.

Two-way ANOVA was conducted for the sediment loads for the first three runs, and the result is presented showed in table 4. The between-subject effects result indicated that the interaction effect between inlets and run was statistically significant (p <0.01), and sediment load from the inlets were significantly different (p <0.01). But there was no significant difference between the sediment loads of each run from the result of series1 (p = 0.84). The multiple comparisons of load result, which corresponded to the concentration result in table 3, showed that the AD inlet resulted in the lowest sediment load (15056.49 mg/min) among the four inlets tested. The sediment load rates for AS, QD, and HB inlets were

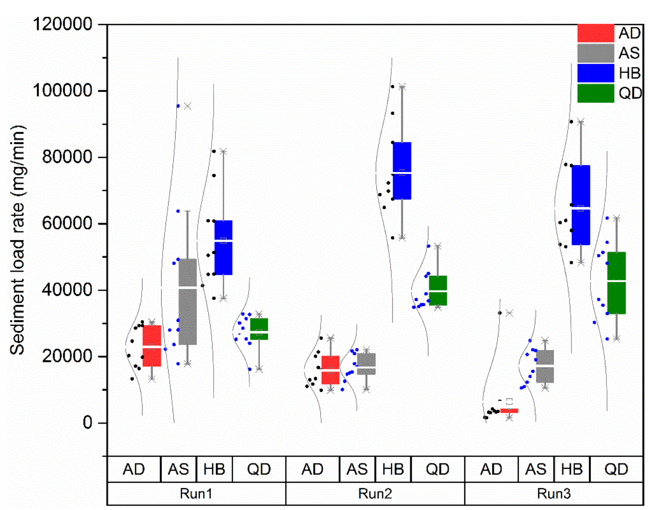

Figure 8. Grouped box chart of sediment load during the first three runs. The white line in the middle of box represented the mean. (dot near box is the sediment concentration data for each inlet; the curve line is the distribution of the data; QD-QuickDrain low profile inlet, AD-AgriDrain wick inlet, HB-Hickenbottom standard inlet, and AS-Ag-Solutions standard inlet).

measured to be 24880.69, 39573.42, and 64919.05 mg/min, respectively. These results indicated that the performance of the four inlets was significantly different from each other. The probable cause for this result is the difference in the inlet design, whether the focus was on controlling flow or sediment.

Inlet Long-Term Performance Tests

For seven of the eight tests performed, the locations of the inlets had no significant effect ($\alpha = 0.05$) on the sediment concentration except for the HB inlet (p = 0.029). In general, the location did not appear to influence inlet performance, and the data for each inlet from its two locations were grouped together for testing the significance of sequence.

Data for each inlet from the two groups for the same position in the series were combined. Thus, data from runs 3 and 6, the first run in each group, were combined. Similarly, the data for runs 4 and 7 were combined, and the data for runs 5 and 8 were also combined. Box plots of the sediment concentrations of the combined datasets are shown in figure 9. In general, sediment decreases with progression through the sequence of runs. The interquartile ranges decreased from the run 3 + run 6 to the run 5 + run 8 in the sequence. The AS inlet has the highest variability of concentration at the beginning of long term test for run 3 + run 6. The AS inlet also had the highest mean sediment concentration (4098.3 mg/L), while the mean sediment concentration for AD, HB, and QD were 3112.2, 3807.5, and 2957.8 mg/L, respectively. The sediment result for each inlet in the run 3+ run 6 was not significantly different from the performance of inlet in run 1 (p >0.05). The run 5+ run 8 result is more representative of the long-term performance of the inlets, after a buildup of sediment. After run 3 + run 6 and run 4 + run 7, the open area of inlet was blocked by deposited sediment. The concentration dropped dramatically during run 5 + run 8 where average sediment concentration for AD, AS, HB, and QD were 898.4, 1048.7, 1045.3, and 1458.2 mg/L, respectively. The filtering function of the deposited sediment around the inlet might be the reason for the sediment concentration decrease during long-term test.

Box plots of the sediment loads of the combined datasets are shown in figure 10. As observed in the sediment concentrations result (fig. 9), sediment load decreased through the sequence of runs for AD, AS, and HB inlets. The exception was with the QD inlet, through which sediment load was constant through sequential runs. This result indicated that QD inlet could maintain high flow rate under long-term unmaintained condition, but it was less effective in controlling sediment loss compared to the other inlets. Because of the high sediment load observed for the QD inlet, the loss of adsorbed pollutant such as phosphorus would also increase for

Table 4. Tests of Between-Subject Effects and multiple comparisons results for sediment concentration in test series 1(runs 1, 2 and 3).

Between-subject Effects						Multiple Comparisons of Inlet					
								Subset (mean) (mg/min)			
Source	df	Mean Square	F	Sig.	Method	Inlet[a]	N	1	2	3	4
Series 1	2	40065096.91	0.174	0.84		AD	30	15065.49			
Load	3	1.41E+10	61.402	0.0001		AS	30		24880.69		
Series 1 load	6	1.69E+09	7.352	0.0001	S-N-K	QD	30			39573.42	
Error	108	2.30E+08				HB	30				64919.05
						Sig.		1.000	1.000	1.000	1.000

[a] QD-QuickDrain low profile inlet, AD-AgriDrain wick inlet, HB-Hickenbottom standard inlet, and AS-Ag-Solutions standard inlet.

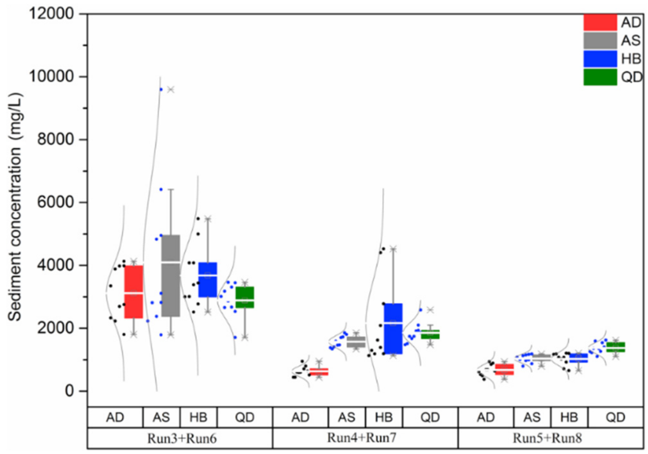

Figure 9. Grouped box chart of sediment concentration data for combined runs. (dots near box is the sediment concentration data for each inlet; the curve line is the distribution of the data; QD-QuickDrain low profile inlet, AD-AgriDrain wick inlet, HB-Hickenbottom standard inlet, and AS-Ag-Solutions standard inlet).

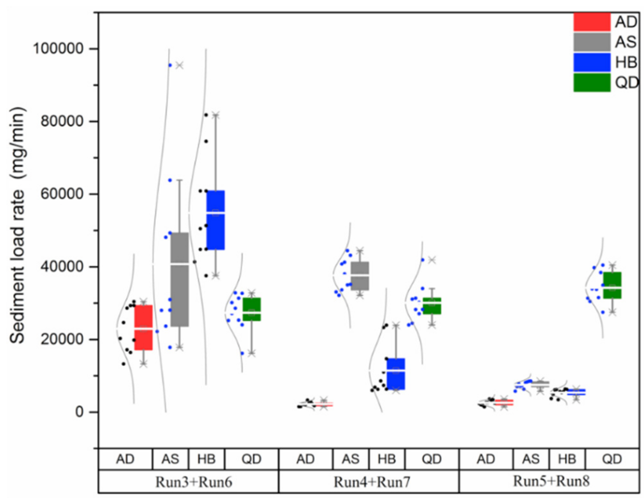

Figure 10. Grouped box chart of sediment load data for combined runs (dot near box is the sediment concentration data for each inlet; the curve line is the distribution of the data; QD-QuickDrain low profile inlet, AD-AgriDrain wick inlet, HB-Hickenbottom standard inlet, and AS-Ag-Solutions standard inlet).

this inlet. The AD inlet led to a low sediment load rate after run 3+ run 5 and run 4 + run 6, which is only 4980.4 mg/min. But AD inlet can also impact the crop yield in a corn field because the higher water table could harm the corn roots. In that situation, the AS inlet which can provide the moderate performance of reducing load and keeping flow rate is a better choice.

Conclusion

The goal of this study was to characterize and compare the performances of four different inlets [QuickDrain low profile inlet (QD), AgriDrain wick inlet (AD), Hickenbottom standard inlet (HB), and Ag-Solutions standard inlet (AS)] for surface water drainage. The laboratory test was geared towards analyzing the inlet performance for flow rate while the field test was designed to evaluate their sediment transport capabilities. The laboratory test results indicated that the AgriDrain inlet had the lowest flow rate for a given flow depth in both debris free and debris condition. Ag Solutions inlet had the highest flow rate under both debris free and debris condition. The flow rate for Hickenbottom inlet was higher than QuickDrain in debris free condition but was similar in debris condition. The rank of inlet performance for flow rate under the debris free condition is AS > HB > QD > AD and while their performance rank based on debris condition is AS > QD = HB > AD. In field tests, AgriDrain inlet resulted in the lowest sediment concentration and load. Compared to Hickenbottom standard inlet, AgriDrain inlet resulted in only 66% average sediment concentration and 23.2% average sediment load. This inlet was the most effective in keeping sediment out of tile lines. However, it would be most ineffective at draining depression during heavy rain events, and would not be the best choice for crops that are sensitive to flooding unless more than one inlet is placed in a depression. Hickenbottom inlet had the highest flow rate for a given flow depth in the field condition and might be the most effective at quickly draining depressions among the four inlets tested. It is best suited for depressions area planted with crops that are sensitive to flooding, in conditions where sediment transport is not a major consideration. The standard Ag-Solutions inlet had relative higher flow rates (compared to QuickDrain and AgriDrain inlets) and moderate sediment loading rate and would be good for both drainage and sediment reduction. The QuickDrain inlet had a consistent sediment loading rate over time and may be least likely to be obstructed by sediment or debris under field conditions. The rank of inlet performance based on the relative sediment concentration is HB > QD > AS > AD and while their performance rank based on sediment load is QD > AS > HB > AD.

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