

PRIVATE PLACEMENT AGREEMENT

\$25,000,000

**DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY
Public Utility Subordinate Lien Multimodal Revenue Bonds, Series 2016B
(Environmental Impact Bonds)**

This Private Placement Agreement, dated September 28, 2016 (as amended, modified or restated from time to time, this “Agreement”), is entered into by and between the District of Columbia Water and Sewer Authority (the “Authority”), and GSUIG Real Estate Member LLC and Calvert Social Investment Foundation, Inc., each a purchaser of the Bonds described herein (and together with their designees, successors and assigns, collectively, the “Purchasers”). Terms used but not defined herein are used as defined in the Indenture identified below.

RECITALS

WHEREAS, the Authority entered into a Consent Decree on March 23, 2005, in Consolidated Civil Action No. 1:00CV00183TFH before the United States District Court for the District of Columbia to implement its Long Term Control Plan (“LTCP”) to control combined sewer overflows (CSOs) into the Anacostia River, Potomac River, and Rock Creek tributaries (“2005 Consent Decree”); and,

WHEREAS, the Authority, the District of Columbia (“District”), the U.S. Environmental Protection Agency (“EPA”), and the U.S. Department of Justice have agreed to a modification of the 2005 Consent Decree on January 14, 2016, amending the LTCP to include the installation of green infrastructure practices in the Rock Creek sewershed and the Potomac River sewershed (“Modified Consent Decree”); and,

WHEREAS, the Authority issued a Request for Proposal (“RFP”), Design and Construction (Design-Build) Services for Green Infrastructure (“GI”), Contract No. 150210 – Rock Creek Project A (Division RC-A), dated July 1, 2016, as amended and supplemented by various Addenda to the RFP (“Addenda”), to procure a qualified service provider to construct GI practices to manage the volume of runoff equivalent to 1.2” of rain falling on a minimum of 20 equivalent impervious acres for the Rock Creek Green Infrastructure Project A (“Project” or “RC-A”); and,

WHEREAS, in order to finance a portion of the costs of the Project, the Authority intends to issue its Public Utility Subordinate Lien Multimodal Revenue Bonds, Series 2016B (Environmental Impact Bonds) (the “Bonds”), which will be issued under the Indenture; and

WHEREAS, the Authority wishes to incorporate a “pay for success” model as an innovative financing mechanism for the Project by making a portion of the payments related to the Bonds contingent upon the effectiveness of GI in managing stormwater runoff in RC-A; and,

WHEREAS, the Authority entered into a Memorandum of Agreement with the District on May 20, 2015, to create a Green Jobs Program (the “Green Jobs Program”) to train and certify District residents to perform construction, inspection, and maintenance work on green infrastructure facilities pursuant to the Modified Consent Decree (“Green Jobs MOA”); and,

WHEREAS, the Purchasers, through their investment in the Bonds, are interested in supporting the Authority’s Green Jobs Program; and,

NOW THEREFORE, the Parties to this Contract, in consideration of the mutual promises, covenants and stipulations set forth herein, agree as follows:

1. **Definitions.** In addition to the terms defined in the recitals and elsewhere in this Agreement and the Indenture, the following terms shall have the following meanings unless the context or use indicates a different meaning:

- a. “1.2” Retention Standard” means the volume of water runoff produced by 1.2” of rain falling on an impervious surface.
- b. “Notice to Proceed” means the Design-Build firm selected by the Authority as a result of its RFP is authorized by the Authority to commence the construction of the Project.
- c. “Outcome Payment” means the amount due from the Authority to the Purchasers in the event of a Tier 1 Outcome as defined in Section 10.
- d. “Project” or “RC-A” means the Rock Creek Green Infrastructure Project A, as defined in the RFP and Addenda, and attached as Exhibit C hereto.
- e. “Purchaser Letter” means a letter substantially in the form attached as Exhibit B hereto.
- f. “Risk Share Payment” means the amount due from the Purchasers to the Authority in the event of a Tier 3 Outcome as defined in Section 10.
- g. “Runoff” means the annual wet weather volume as expressed in millions of gallons per average year.
- h. “Runoff Reduction” means the percentage reduction of Runoff in RC-A per impervious acre treated to manage the volume of runoff produced by 1.2” of rain as compared to the existing conditions Runoff in RC-A as defined in Section 9.
- i. “Technical Memorandum” means the Environmental Impact Bond Technical Evaluation Memorandum dated September 13, 2016, issued by the Authority and accepted and agreed to by the Purchasers, and attached as Exhibit D hereto.
- j. “Mandatory Tender Date” means April 1, 2021.

2. **Purchase and Sale of Bonds.** On the terms and conditions and on the basis of the representations, warranties, covenants and agreements set forth herein, the Purchasers hereby agree to purchase from the Authority, and the Authority hereby agrees to sell and deliver to the Purchasers, all (but not less than all) of \$25,000,000 aggregate principal amount of the District of Columbia Water and Sewer Authority Public Utility Subordinate Lien Multimodal Revenue Bonds, Series 2016B (Environmental Impact Bonds), of which \$23,000,000 of the Bonds shall be purchased by GSUIG Real Estate Member LLC and \$2,000,000 of the Bonds shall be purchased by Calvert Social Investment Foundation, Inc. The proceeds of the Bonds will be used to (i) pay a portion of the costs of the Project, and (ii) pay costs of issuing the Bonds. The purchase price of the Bonds will be \$25,000,000, representing the aggregate principal amount of the Bonds. The Bonds will mature on the dates and in the amounts and will bear interest and will be subject to redemption prior to maturity as set forth in Exhibit A hereto.

3. **Bond Authorization.** The Bonds shall be issued under and pursuant to provisions of the laws of the United States of America and the District, including particularly, an act of the Council of the District entitled the “Water and Sewer Authority Establishment and Department of Public Works Reorganization Act of 1996,” as amended, codified at District of Columbia Official Code Ann. Sections 34-2201.01 *et seq.*, and the acts amendatory thereof and supplemental thereto (the “Act”), and an act of the United States Congress entitled the “District of Columbia Water and Sewer Authority Act of 1996” (Public Law 104-184), as amended (the “Federal Act”), and all proceedings necessary to authorize and provide for the issuance of the Bonds, including a resolution adopted by the Board of Directors of the Authority, dated September 1, 2016 (the “Resolution”), and the Master Indenture of Trust, dated as of April 1, 1998 (the “Master Indenture”), between the Authority and Wells Fargo Bank, N.A., as trustee (the “Trustee”), as amended and supplemented, including by the Twenty-First Supplemental Indenture of Trust, dated as of the Closing Date (as defined below) (the “Twenty-First Supplemental Indenture,” and together with the Master Indenture as previously amended and supplemented, the “Indenture”), between the Authority and the Trustee, substantially in the forms previously delivered to us.

4. **Closing.** At 10:00 a.m. New York City Time on September 29, 2016, or at such other time and date as may be agreed upon by the Authority and the Purchasers (the “Closing Date”), the Authority will, subject to the terms and conditions hereof, deliver the Bonds to the Purchasers in definitive form, duly executed and authenticated, together with the other documents hereinafter required, and, subject to the terms and conditions hereof, the Purchasers will accept such delivery and pay the purchase price of the Bonds as set forth in Section 2 hereof in federal funds to the order of the Authority (the “Closing”). The Authority shall be under no obligation to deliver any of the Bonds unless the Purchasers shall have paid the purchase price for all the Bonds. The Bonds shall be so issued and registered to and held by the Purchasers, or as otherwise directed by the Purchasers. The Closing will occur at the offices of Squire Patton Boggs (US) LLP, Washington, D.C., or such other place as may be agreed on by the Authority and the Purchasers.

5. **Representations, Warranties and Covenants of the Authority.** The Authority hereby represents, warrants, covenants and agrees as follows:

a. The Authority is, and at the Closing Date will be, a duly organized and validly existing corporate body and independent authority of the District established under the laws of the United States and the District, including the Act and the Federal Act, with the full legal right, power and authority to (i) adopt the Resolution, (ii) execute, deliver and perform its obligations under this Agreement, the Indenture, and the Certificate of Award of the Authority establishing the purchase price, maturities, interest rates, redemption provisions and other terms of the Bonds, dated the date hereof (the "Certificate of Award" and, together with this Agreement and the Indenture, the "Bond Documents"), (iii) perform its obligations under the Water Sales Agreement, dated as of July 31, 1997, between the Authority and the United States of America, acting through the Secretary of the Army (the "Water Sales Agreement") and the Blue Plains Intermunicipal Agreement of 2012 between the District; Fairfax County, Virginia; Montgomery County, Maryland; Prince George's County, Maryland; and the Washington Suburban Sanitary Commission (the "IMA," and together with the Water Sales Agreement, the "System Agreements"), (iv) sell, issue and deliver the Bonds to the Purchasers as provided herein, and (v) carry out and consummate the transactions contemplated by the Resolution, the Bond Documents and the System Agreements; and the Authority has complied, and at the Closing Date will be in compliance, in all respects, with the Act and the Federal Act and with the obligations on its part in connection with the issuance of the Bonds contained in the Bonds and Bond Documents.

b. The Authority (i) has duly and validly adopted the Resolution, (ii) has authorized the execution and delivery of the Bond Documents, (iii) is authorized to execute, issue, sell and deliver the Bonds, (iv) is authorized to appoint, and has appointed, Wells Fargo Bank, N.A., as Trustee, (v) is authorized to apply and will apply the proceeds of the Bonds as provided in and subject to all of the terms and provisions of the Resolution, including the payment or reimbursement of the Authority expenses incurred in connection with the negotiation, sale, issuance and delivery of the Bonds to the extent required by Section 14, and (vi) has taken or will take on or before the Closing Date, all action necessary or appropriate for (a) execution, issuance, sale and delivery of the Bonds to the Purchasers, (b) approval, execution and delivery of and the performance by the Authority of its obligations contained in the Bonds and the Bond Documents, and (c) the consummation by it of all other transactions contemplated by the Bond Documents and any and all such other agreements and documents as may be required to be executed, delivered or received by the Authority in order to carry out, give effect to, and consummate those transactions.

c. The adoption of the Resolution, the execution and delivery of the Bond Documents, the execution, issuance, sale and delivery of the Bonds and the performance by the Authority of its obligations hereunder and thereunder, and the performance by the Authority of its obligations under the System Agreements are within the corporate powers of the Authority and are not in conflict with and will not constitute a breach, default or result in a violation of (i) the Act, (ii) any federal constitutional or federal or District statutory provision, including the Federal Act, (iii) any agreement or other

instrument to which the Authority is a party, or (iv) any order, rule, regulation, decree or ordinance of any court of competent jurisdiction, government or governmental authority having jurisdiction over the Authority or its property.

d. The District has authorized the Authority to use all of the property and assets of the water distribution and wastewater collection, treatment and disposal systems of the Authority (the "System"), uninterrupted by the District, for as long as any revenue bonds of the Authority, including the Bonds, remain outstanding. The Authority has the full legal right, power and authority to operate the System and to collect and pledge the Revenues therefrom in accordance with the Indenture.

e. The Resolution or other appropriate actions adopted or taken by the Authority establishing the current rates, fees and charges for services of the System have been duly adopted or taken and are in full force and effect.

f. The System Agreements and all other agreements, permits, licenses, consents, approvals, actions, consent decrees and settlement orders material to the operation and management of the System, including the collection of the Revenues, are in full force and effect as of the date hereof and will be on the Closing Date, and the Authority is not and will not be in default thereunder or in breach thereof. The System Agreements have been duly authorized, executed and delivered by the Authority and constitute valid and binding obligations of the Authority enforceable in accordance with their respective terms, subject to applicable bankruptcy, insolvency and similar laws affecting creditors' rights generally and subject, as to enforceability, to general principles of equity.

g. The Bonds, when issued, delivered to the Purchasers and paid for, in accordance with the Act, the Resolution, the Indenture and this Agreement, will have been duly authorized, executed, issued and delivered by the Authority and will constitute valid and binding obligations of the Authority, enforceable against the Authority in accordance with their terms, subject to applicable bankruptcy, insolvency, reorganization, moratorium and similar laws affecting creditors' rights generally and subject, as to enforceability, to general principles of equity. The Bonds are not a pledge of and do not involve the faith and credit or the taxing power of the District, and the District shall not be liable thereon.

h. This Agreement constitutes, and, upon execution and delivery by the Authority and the other parties thereto, each of the other Bond Documents will constitute, the valid, binding and enforceable obligation of the Authority in accordance with their respective terms, subject to applicable bankruptcy, insolvency, and similar laws affecting creditors' rights generally and subject, as to enforceability, to general principles of equity.

i. The Authority is not in material breach of or material default under any applicable constitutional provision or law of the United States, the District or any applicable judgment or decree, or any loan agreement, indenture, bond, note, resolution, agreement or other instrument to which it is a party or to which it or any of its property or

assets is otherwise subject, and no event has occurred and is continuing which, with the passage of time or the giving of notice, or both, would constitute a default or event of default under any such instrument; and the execution and delivery of the Bonds and the Bond Documents and the adoption of the Resolution, and compliance with the provisions contained therein and herein, and in the System Agreements, do not conflict with or constitute a breach of or default under any constitutional provision, law, administrative regulation, judgment, decree, loan agreement, indenture, bond, note, resolution, agreement, or other instrument to which it is a party or any of its property or assets are otherwise subject, nor will any such execution, delivery, adoption, or compliance result in the creation or imposition of any lien, charge, or other security interest or encumbrance of any nature whatsoever upon any of its property or assets or under the terms of any such law, regulation or instrument, except as provided by the Bonds.

j. All authorizations, approvals, licenses, permits, consents and orders of any governmental authority, legislative body, board, agency or commission having jurisdiction of the matter have been duly obtained or, with respect to the issuance of the Bonds, will be obtained prior to the issuance of the Bonds, which are required for the due authorization by or which would constitute a condition precedent to or the absence of which would materially adversely affect the due performance by the Authority of its obligations in connection with the issuance of the Bonds and under this Agreement, except for such approvals, consents and orders as may be required under the Blue Sky or securities laws of any state in connection with the sale of the Bonds.

k. There is no litigation, action, suit, proceeding, inquiry or investigation, at law or in equity, before or by any court, government agency, public board or body, pending or, to the best knowledge of the Authority, threatened against the Authority (i) affecting or seeking to prohibit, restrain or enjoin the issuance, sale or delivery of the Bonds or the collection of the Revenues pledged to the payment of the principal of and interest on the Bonds, (ii) in any way contesting or affecting any authority for the issuance of the Bonds or the validity, enforceability, due authorization, execution or delivery of the Bonds, including this Agreement and the other Bond Documents, or the validity or enforceability of the System Agreements, nor, to the best knowledge of the Authority, is there any basis therefor, wherein an unfavorable decision, ruling or finding would materially adversely affect the validity or enforceability of the Bonds or the Bond Documents, (iii) questioning the tax-exempt status of the Bonds under the laws of the District, (iv) affecting or in any way contesting the corporate existence or powers of the Authority or the titles of the officers of the Authority to their respective offices, or (v) except as described in writing delivered to the Purchase by the Authority, which may result in any material adverse change in the business or the financial condition or the financial prospects of the Authority.

l. The audited financial statements of the Authority for the years ended September 30, 2014, and September 30, 2015, including the statements of net position; revenues, expenses and changes in net position; and cash flows for the fiscal year ended on such date, as previously delivered by the Authority to the Purchasers, are true, complete and correct and fairly present the financial condition of the Authority as of such date and the results of its operations for such fiscal years. There has been no material

adverse change in the financial condition of the Authority since September 30, 2015, except as described by the Authority in writing delivered to the Purchasers.

m. The Authority has not been notified of any listing or proposed listing by the Internal Revenue Service to the effect that the Authority is a bond issuer whose arbitrage certificates may not be relied upon.

n. Any certificate signed by an authorized delegate of the Authority in connection with the transactions described in this Agreement will be deemed a representation, warranty, covenant and agreement by the Authority to the Purchasers as to the statements made therein.

o. Prior to the Closing, the Authority will not take any action within or under its control that will cause any adverse change of a material nature in the Authority's financial position, or its results of operations or condition, financial or otherwise.

p. The Authority will not, prior to the Closing, offer or issue any bonds, notes or other obligations for borrowed money or incur any material liabilities, direct or contingent, except in the ordinary course of business, without the prior approval of the Purchasers.

6. **Conditions to Obligations of Purchasers at Closing.** The Purchasers have entered into this Agreement in reliance on the representations, warranties, covenants and agreements of the Authority contained herein, and in reliance on the representations, warranties, covenants and agreements to be contained in the documents and instruments to be delivered at the Closing and on the performance by the Authority of its obligations hereunder, as of the Closing Date. Accordingly, the Purchasers' obligations under this Agreement to purchase, to accept delivery of and to pay for the Bonds are conditioned on the performance by the Authority of its obligations to be performed hereunder and the delivery of such documents and instruments enumerated herein in form and substance reasonably satisfactory to the Purchasers, at or before the Closing, and are also subject to the following additional conditions:

a. The representations, warranties, covenants and agreements of the Authority contained herein are true, complete and correct on the date hereof and on and as of the Closing Date, as if made on the Closing Date;

b. The provisions of the Act and the Federal Act, as in effect on the date of this Agreement, shall be in full force and effect and shall not have been amended, except as to amendments which, in the reasonable opinion of the Purchasers, are not adverse to the interest of the Purchasers;

c. At the time of the Closing, the Resolution is in full force and effect in accordance with its terms and has not been amended, modified or supplemented;

d. At the time of the Closing, all official action of the Authority relating to the Bonds, the Bond Documents and the System Agreements are in full force and effect in accordance with their respective terms and have not been amended, modified or supplemented, except in each case as may have been agreed to by the Purchasers;

e. At the time of the Closing the Authority will perform or will have performed all of its obligations required under, specified in or contemplated by this Agreement, the Resolution and the Indenture, to be performed prior to the Closing; and

f. At or before the Closing, the Purchasers will have received true and correct copies of each of the following documents:

i. A certified copy of the Resolution;

ii. Counterparts of each of the fully executed Bond Documents and the System Agreements;

iii. The approving opinion of Bond Counsel, dated the Closing Date, in form and substance satisfactory to the Purchasers, and a reliance letter with respect to such opinion addressed to Wells Fargo Bank, N.A., as Trustee;

iv. An opinion, dated the Closing Date, of the General Counsel to the Authority, substantially in the form of Exhibit E hereto;

v. A Tax Compliance Certificate of the Authority, with attachments, dated the Closing Date;

vi. One or more certificates of the Authority, dated the Closing Date, (A) to the effect that the representations, warranties, covenants and agreements of the Authority herein are true and correct on and as of the Closing Date as if made on the Closing Date, and that the Authority has performed all obligations to be performed hereunder as of the Closing Date; (B) to the effect that the Bond Documents, the Bonds and the System Agreements have not been modified, amended or repealed after the date hereof without the written consent of the Purchasers; and (C) to the effect that no material change has occurred with respect to the System from the period from the date of this Agreement through the Closing Date; and

vii. Such additional legal opinions, certificates, instruments and other documents as the Purchasers may reasonably request to evidence the truth and accuracy, as of the Closing Date, of the Authority's representations, warranties, covenants and agreements contained herein and the due performance or satisfaction by the Authority on or prior to the Closing Date of all the agreements then to be performed and conditions then to be satisfied by it.

g. At the time of the Closing, the Authority will have received a legal enforceability opinion of the Purchasers' legal counsel substantially in the form of Exhibit F hereto.

All the opinions, letters, certificates, instruments and other documents mentioned above or elsewhere in this Agreement will be deemed to be in compliance with the provisions hereof if, but only if, they are in form and substance satisfactory to the Purchasers.

7. **Obligations upon Cancellation.** If the Authority is unable to satisfy the conditions to the obligations of the Purchasers to purchase, to accept the delivery of and to pay for the Bonds contained in this Agreement, or if the obligations of the Purchasers to purchase, to accept delivery of and to pay for the Bonds is terminated for any reason permitted by this Agreement, this Agreement will terminate and neither the Purchasers nor the Authority will be under any further obligation hereunder, except that the Authority and the Purchasers shall pay their respective expenses as set forth in Section 14.

8. **Project Construction.** The Authority shall be responsible for the construction of the Project in accordance with the requirements contained in the RFP and Addenda and in compliance with the Modified Consent Decree. The Parties recognize and agree that certain changes to the Project will occur in the normal course of construction due to various factors including, but not limited to, third party requirements, unanticipated site conditions, and design and construction modifications to improve the performance of the Project. The Authority will use its best efforts to cause changes to be consistent with the Modified Consent Decree requirement to manage 20 impervious acres to the 1.2" Retention Standard. Such changes will be summarized in the monthly construction reports provided to the Purchasers as described in Section 11 and will be documented in the Record Drawing completed after the Project has been placed into operation. The Authority will provide the Purchasers with the Record Drawing of the Project within 30 days of its receipt.

9. **Project Evaluation.** The Authority and the Purchasers agree that the Project will be evaluated on the basis of the Runoff Reduction. The Authority and the Purchasers further agree that the evaluation will be carried out and the Runoff Reduction will be calculated in accordance with the methodology described in the Technical Memorandum. The Authority and the Purchasers acknowledge and agree as follows:

a. **Pre-Construction Monitoring.** The Authority has been performing pre-construction monitoring since January 2016. The results of the pre-construction monitoring during the periods identified in the Technical Memorandum have been used by the Authority to determine the existing conditions Runoff in the RC-A area prior to the beginning of construction of the Project and to estimate the Runoff Reduction expected under future conditions after completion of the Project.

b. **Post-Construction Monitoring.** After the Project is placed into operation, the Authority will perform at least 12-months of post-construction monitoring (the "Post-Construction Monitoring Period"). The Post-Construction Monitoring Period will start no later than 3 months after the Authority certifies to the EPA and the Purchasers that the project has been placed into operation. The Authority will provide notice to the Purchasers of the conclusion of the Post-Construction Monitoring Period. The results developed during the Post-Construction Monitoring Period will be used by the Authority to determine the actual conditions Runoff and the corresponding Runoff Reduction related to the Project in the same manner and method that the results of the pre-construction monitoring were used by the Authority to determine the runoff qualities for existing conditions.

c. Right of Inspection. During the Post-Construction Monitoring Period and prior to the issuance of the Final Report by the Authority described in paragraph (d) below, and at their own expense, the Purchasers may undertake an independent evaluation of the Project to ascertain whether it was constructed in material compliance with the design of the Project as described in Section 8 and the requirements of the Modified Consent Decree.

d. Final Report. The Authority will issue a report to the Purchasers and the Independent Validator documenting the calculation of the Runoff Reduction within 180 days of the conclusion of the Post-Construction Monitoring Period (“Final Report”). The results contained in the Final Report will serve as the basis for determining the effectiveness of the Project, as described below, in Section 10.

e. Independent Validator. Prior to the conclusion of the Post-Construction Monitoring Period, the Purchasers and the Authority will select, subject to mutual consent of the Parties not to be unreasonably withheld, an independent third-party to validate the results contained in the Final Report (“Independent Validator”). The Independent Validator will issue an opinion as to whether the Authority’s calculation of the Runoff Reduction complies with the methodology described in the Technical Memorandum in all material respects. The payment of an Outcome Payment or Risk Share Payment shall be conditioned upon receipt of the Independent Validator’s opinion confirming such compliance. The parties agree that the Independent Validator shall deliver its opinion to the Authority and to the Purchasers at the same time. The Independent Validator’s opinion shall be due no later than 45 days after submittal of the Final Report (the “Final Report Due Date”), but any failure by the Independent Validator to deliver its opinion by the Final Report Due Date shall not affect any right or obligation of the Authority or the Purchasers to pay or receive the Outcome Payment or Risk Share Payment, as the case may be; provided however, that unless the Authority shall have failed to deliver a Final Report by 90 days prior to the Mandatory Tender Date (with the consequence of such failure specified in Section 10.e.), if the Independent Validator fails to deliver its opinion on or before the Mandatory Tender Date, then:

i. Subject to paragraphs (ii.) and (iii.) below, the Authority shall make payment on the Mandatory Tender Date to the Trustee, for the benefit of the Purchasers, of all Principal and Interest due on the Bonds without any addition to or reduction from that payment related to the Outcome Payment or Risk Share Payment; and

ii. If the Final Report had indicated a Tier 3 Outcome, then promptly on the Mandatory Tender Date, the Purchasers shall provide the Trustee (either as Trustee or in a separate custodial role) an irrevocable direction to withhold from any payment the Purchasers receive under clause (i) above the full amount of the potential Risk Share Payment and to deposit that amount in escrow (the “Risk Share Escrow Deposit”) and to hold that amount in escrow unless and until it is either required to be disbursed to the Authority or released back to the Purchasers, pursuant to clause (iv) below, at such time as it is determined that the Risk Share Payment is or is not payable to the Authority, and if, for any reason, the Trustee

declines or fails to do so, then the Purchasers shall make the same escrow arrangements and give effect to them with a third-party custodian acceptable to the Authority; and

iii. If the Final Report had indicated a Tier 1 Outcome, then promptly on the Mandatory Tender Date, the Authority shall (a) pay to the Trustee the full amount owed under (i) above plus the full amount of the potential Outcome Payment and (b) provide to the Trustee (either as Trustee or in a separate custodial role) an irrevocable direction to deposit the Outcome Payment in escrow (the “Outcome Payment Escrow Deposit”) and to hold the Outcome Payment Escrow Deposit in escrow unless and until it is either required to be disbursed to the Purchasers or released back to the Authority, pursuant to clause (iv) below, at such time as it is determined that the Outcome Payment is or is not payable to the Purchasers, and if, for any reason, the Trustee declines or fails to give effect to those escrow arrangements, then the Authority shall make the same escrow arrangements and give effect to them with third-party custodian acceptable to the Purchasers; and

iv. At such time after the Mandatory Tender Date as both parties have received the Independent Validator’s opinion, then, within thirty (30) days of such receipt, (a) if the opinion confirms that the Authority owes the Outcome Payment to the Purchasers, the Trustee shall release the Outcome Payment Escrow Deposit to the Purchasers in accordance with the Purchasers’ payment instructions; provided, however, that if the opinion determines that the Authority does not owe the Outcome Payment to the Purchasers, the Trustee shall release the Outcome Payment Escrow Deposit to the Authority in accordance with the Authority’s payment instructions, or (b) if the opinion confirms that the Purchasers owe the Risk Share Payment to the Authority, the Trustee shall release the Risk Share Escrow Deposit to the Authority in accordance with the Authority’s payment instructions; provided, however, that if the opinion determines that the Purchasers do not owe the Risk Share Payment to the Authority, the Trustee shall release the Risk Share Escrow Deposit to the Purchasers in accordance with the Purchasers’ payment instructions; and

v. If for any reason the Independent Validator has not delivered its opinion within 45 days after the Mandatory Tender Date, then either (a) the Authority and the Purchasers shall agree upon a later date by which the Independent Validator’s opinion shall be due, (b) the Authority and the Purchasers shall appoint a new Independent Validator that will have an additional 45 days (or such other period of time as the Authority and the Purchasers may agree upon) to render an opinion, or (c) the Authority and the Purchasers shall agree that neither the Outcome Payment nor the Risk Share Payment shall be payable.

10. **Performance Tiers, Outcome Payment and Risk Share Payment.** The Purchasers shall be entitled to receive the Outcome Payment from the Authority, and the Authority shall be entitled to receive the Risk Share Payment from the Purchasers based on the results of the project evaluation:

a. The effectiveness of the Project will be determined by the Authority based upon the results contained in the Final Report as corresponding to one of three (3) Performance Tiers.

i. Tier 1. A “Tier 1 Outcome” will be a Runoff Reduction greater than 41.3%;

ii. Tier 2. A “Tier 2 Outcome” will be a Runoff Reduction ranging from 18.6% to 41.3%; or

iii. Tier 3. A “Tier 3 Outcome” will be a Runoff Reduction less than 18.6%.

b. Subject to Section 9.e., on the Mandatory Tender Date, the Authority will make a payment of any and all amounts due to the Purchasers of the Bonds under this Agreement.

i. Tier 1. The Authority will make a payment of any and all amounts due to the Purchasers, including Principal, Interest and Outcome Payment.

ii. Tier 2: The Authority will make a payment of any and all amounts due to the Purchasers, including Principal and Interest.

iii. Tier 3: The Authority will make a single net payment of any and all amounts due to the Purchasers, including Principal and Interest less Risk Share Payment due to the Authority. The single net payment will constitute full payment of principal and interest due on the Bonds, and shall in no event constitute an Event of Default.

c. The amount of the Outcome Payment will be \$3,300,319.00, and the amount of the Risk Share payment will be \$3,300,319.00.

d. Any Outcome Payment or Risk Share Payment, whether contingent or actual, shall not constitute or be treated as principal of or interest on the Series 2016B Bonds for any purpose of the Indenture, including, without limitation, the Rate Covenant or any conditions for the issuance of Bonds or Subordinate Debt. An Outcome Payment will not constitute Senior Debt or Subordinate Debt under the Master Indenture. An Outcome Payment will be secured by a promise to pay from Net Revenues that is subordinate to the pledge of Net Revenues that secures the Outstanding Senior Debt and any other Senior Debt that the Authority may issue from time to time in the future, and subordinate to the pledge of Net Revenues that secures the Outstanding Subordinate Debt and other Subordinate Debt that the Authority may issue from time to time in the future.

e. **Project Delays.** If the Authority fails to deliver the Final Report on or before 180 days after the conclusion of the Post-Construction Monitoring Period, the Authority shall have an additional period of time extending to 90 days prior to the Mandatory Tender Date to submit the Final Report. The Independent Validator shall then issue an opinion confirming the Runoff Reduction contained in the Final Report. If the Authority fails to deliver a Final Report by 90 days prior to the Mandatory Tender Date, the Parties hereby agree that the effectiveness of the Project will be established as Tier 1 and an Outcome Payment will become due at the Mandatory Tender Date.

11. **Reporting.** The Authority will provide to the Purchasers reports on the status of the Project in accordance with the following:

a. **Construction Progress.** Beginning with the third full month after the Authority has issued a Notice to Proceed for construction of the Project, and every month thereafter until the conclusion of the Post-Construction Monitoring Period, the Authority will provide monthly construction progress reports to the Purchasers within 30 days of the end of each month. In no event shall the Authority's failure to timely provide any such reports be deemed an Event of Default with respect to the Bonds or affect the payment of an Outcome Payment or Risk Share Payment.

i. Beginning six months after the Authority has issued a Notice to Proceed for construction of the Project, and every three-month period thereafter until the conclusion of the Post-Construction Monitoring Period, the Purchasers may schedule a conference call with the Authority at a mutually agreeable and convenient time to review the monthly construction progress reports and discuss construction progress. In no event shall the Authority's failure to timely schedule any such conference calls be deemed an Event of Default with respect to the Bonds or affect the payment of an Outcome Payment or Risk Share Payment.

ii. Beginning six months after the Authority has issued a Notice to Proceed for construction of the Project, and every six-month period thereafter until the Project is placed into operation, the Purchasers may also conduct a site visit at a mutually agreeable and convenient time of the Project to inspect construction progress. During the Post-Construction Monitoring Period, the Purchasers may also conduct a site visit on a quarterly (three-month period) basis at a mutually agreeable and convenient time of the Project to inspect maintenance of the green infrastructure practices. In no event shall the failure of a site visit to occur be deemed an Event of Default with respect to the Bonds or affect the payment of an Outcome Payment or Risk Share Payment.

b. **Green Jobs.** Pursuant to the Green Jobs MOA, the Authority is required to submit on a biannual basis a progress report to the District ("Green Jobs Report"). Within 15 days of the submission of the Green Jobs Report to the District, the Authority shall provide a copy of the Green Jobs Report to the Purchasers until the Mandatory Tender Date. In no event shall the Authority's failure to timely provide any such reports be deemed an Event of Default with respect to the Bonds or affect the payment of an Outcome Payment or Risk Share Payment.

12. **Publicity.** The Authority and the Purchasers together shall jointly develop a plan for the public announcement, including the date of the announcement, of the Bonds to include press releases, fact sheets and other supporting materials. Following the public announcement of the Bonds, the Parties may engage in publicity efforts, such as media requests, press conferences, press statements, interviews, presentations, and blog posts, provided that the Parties may only share information contained in the press release, fact sheet, and other supporting materials including this Agreement and exhibits thereto. These materials may be modified with unanimous consent of the Parties, which consent shall not be unreasonably withheld. Except as otherwise required by law or regulation, the Parties shall advise each other of media inquiries relating to the Bonds and provide advance notice of any planned public communications that specifically relate to the Bonds.

13. **No Advisory or Fiduciary Role.** The Authority acknowledges and agrees that (i) the transactions contemplated by this Agreement are arm's length, commercial transactions between the Authority and the Purchasers in which the Purchasers are each acting solely as a principal and are not acting as an agent, a municipal advisor, financial advisor or fiduciary to the Authority, (ii) the Purchasers have not assumed any advisory or fiduciary responsibility to the Authority with respect to the transactions contemplated hereby and the discussions, conferences, negotiations, undertakings and procedures leading thereto (irrespective of whether the Purchasers or its affiliates have provided other services or are currently providing other services to the Authority on other matters), (iii) the only obligations the Purchasers have to the Authority with respect to the transaction contemplated hereby expressly are set forth in this Agreement, (iv) the Authority has consulted its own financial and/or municipal, legal, accounting, tax, and other advisors, as applicable, to the extent it has deemed appropriate, and (v) this Agreement expresses the entire relationship between the parties hereto.

14. **Expenses.** The Authority shall reimburse the Purchasers for up to \$200,000 for expenses incurred in connection with their purchase of the Bonds, provided such expenses are documented in reasonable detail to the satisfaction of the Authority, including, but not limited to, legal and other professional advisory fees, travel, closing costs, and other such out-of-pocket expenses. The Authority shall pay the costs of the Independent Validator.

15. **Notices.** Any notice or other communication to be given to the Authority or the Purchasers under this Agreement may be given by delivering the same in writing to:

The Authority: District of Columbia Water and Sewer Authority
5000 Overlook Avenue, SW
Washington, DC 20032
Attention: Chief Financial Officer

The Purchaser: GSUIG Real Estate Member LLC
200 West Street
New York, New York 10282
Attention: Michael Lohr

with a copy to: GSUIG Real Estate Member LLC
200 West Street
New York, New York 10282
Attention: Urban Investment Group Portfolio
Manager

with a copy to: gs-uig-portfolio-manager@gs.com

with a copy to: gs-uig-docs@gs.com

The Purchaser: Calvert Social Investment Foundation, Inc.
7315 Wisconsin Avenue NW
Suite 1000W
Bethesda, Maryland 20814
Attention: Beth Bafford

with a copy to: Calvert Social Investment Foundation, Inc.,
7315 Wisconsin Avenue NW
Suite 1000W
Bethesda, Maryland 20814
Attention: Sheila Saxton

with a copy to: Orrick, Herrington & Sutcliffe LLP
1152 15th Street NW
Washington, D.C. 20005
Attention: Darrin L. Glymph, Esq.

16. **Successors and Assigns.** During the Initial Period, (i) the Purchasers shall not sell, assign or transfer the Series 2016B Bonds or any interest therein without the written consent of the Authority, (ii) the Purchasers shall not sell, assign or transfer its right to receive any Outcome Payment or its obligation to make any Risk Share Payment, or any interest in either, without the written consent of the Authority, and (iii) the Authority shall not sell, assign or transfer its right to receive any Risk Share Payment or its obligation to make any Outcome Payment, or any interest in either, without the written consent of the Purchasers. During any subsequent Interest Period, the Holder of any Series 2016B Bond may sell, assign or transfer any Series 2016B Bond at the times, in the manner and subject to the conditions and requirements of the Indenture.

17. **Parties in Interest; Survival of Representations and Warranties.** This Agreement, when accepted in accordance with the provisions hereof, shall constitute the entire agreement between the Authority and the Purchasers and is made solely for the benefit of the Authority and the Purchasers (including the successors or assigns of the Authority or the Purchasers) and no other person will acquire or have any right hereunder or by virtue hereof. All of the Authority's and Purchaser's representations, warranties, covenants and agreements contained in this Agreement will remain operative and full force and effect regardless of (a) any investigations made by or on behalf of the Purchasers, or (b) delivery of and payment for the Bonds pursuant to this Agreement.

18. **Agreement among the Purchasers.** The Purchaser holding a majority in principal amount of the Bonds then Outstanding shall, after the Closing Date, have the exclusive right to provide consents and approvals and exercise and enforce all privileges and rights available to a Purchaser under this Agreement and any of the related Bond Documents; provided, that, the approval of all Purchasers shall be required for any consent, approval or remedy relating to the Mandatory Tender Date or the interest rate on the Bonds. Notwithstanding anything herein to the contrary, this Section shall not apply to any changes to Section 10 of this Agreement nor the publicity rights provided in Section 12 of this Agreement.

19. **Exhibits.** All exhibits referenced in this Agreement and attached to it shall constitute part of this Agreement and shall be incorporated by reference into the Agreement.

20. **Effective Date.** This Agreement will become effective on and as of the date stated in the preamble of this Agreement.


21. **Execution in Counterparts.** This Agreement may be executed in counterparts each of which shall be regarded as an original and all of which shall constitute one and the same document.

22. **Finder.** The Authority represents and warrants that no finder or other agent of a finder has been employed or consulted by it in connection with this transaction.

23. **Severability.** If any provision of this Agreement shall be held invalid by any court of competent jurisdiction, such holding shall not invalidate any other provision hereof and this Agreement shall be construed and enforced as if such illegal provision had not been contained herein.

24. **Governing Law.** This Agreement shall be governed by and construed in accordance with the laws of the District of Columbia.

**DISTRICT OF COLUMBIA WATER
AND SEWER AUTHORITY**

By: 

Name: Mark T. Kim

Title: Chief Financial Officer

PURCHASERS:

GSUIG REAL ESTATE MEMBER LLC

By: 

Name: Margaret Anadu

Title: Authorized Signatory

**CALVERT SOCIAL INVESTMENT
FOUNDATION, INC.**

By: _____

Name: Catherine Godschalk

Title: Vice President, Investments

24. **Governing Law.** This Agreement shall be governed by and construed in accordance with the laws of the District of Columbia.

**DISTRICT OF COLUMBIA WATER
AND SEWER AUTHORITY**

By: _____
Name: Mark T. Kim
Title: Chief Financial Officer

PURCHASERS:

GSUIG REAL ESTATE MEMBER LLC

By: _____
Name: Margaret Anadu
Title: Authorized Signatory

**CALVERT SOCIAL INVESTMENT
FOUNDATION, INC.**

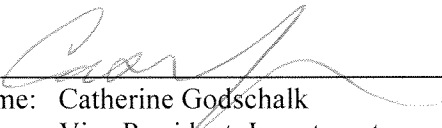
By:  _____
Name: Catherine Godschalk
Title: Vice President, Investments

EXHIBIT A

\$25,000,000

**DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY
Public Utility Subordinate Lien Multimodal Revenue Bonds, Series 2016B
(Environmental Impact Bonds)
(Initial Long-Term Rate Period)**

Term Bonds

\$25,000,000 Term Bonds due October 1, 2046 Priced to Yield 100.00%
(the Bonds shall initially bear interest at a Long-Term Rate of 3.43%)

TERMS OF REDEMPTION

OPTIONAL REDEMPTION AND MANDATORY TENDER

The Bonds are subject to redemption prior to maturity, in whole on April 1, 2021 at a redemption price equal to par, together with accrued interest to the redemption date.

The Bonds are subject to mandatory tender for purchase by the Tender Agent at the Purchase Price on April 1, 2021.

MANDATORY SINKING FUND REDEMPTION

The Bonds are required to be redeemed prior to maturity on October 1 in years and amounts upon payment of 100% of the principal amount thereof plus interest accrued to the redemption date, as follows:

<u>Year</u>	<u>October 1 Redemption Amount</u>
2043	\$6,250,000
2044	\$6,250,000
2045	\$6,250,000
2046*	\$6,250,000

* stated maturity

EXHIBIT B

Form of Purchaser Acknowledgement Letter

September 29, 2016

District of Columbia Water and Sewer Authority
5000 Overlook Avenue, S.W.
Washington, D.C. 20032

Re: \$25,000,000 District of Columbia Water and Sewer Authority Public Utility Subordinate
Lien Multimodal Revenue Bonds, Series 2016B (Environmental Impact Bonds)

GSUIG Real Estate Member LLC and Calvert Social Investment Foundation, Inc., each a purchaser (collectively, the “Purchasers”) of the bonds described above (the “Bonds”) issued by the District of Columbia Water and Sewer Authority (the “Issuer”). This letter is delivered pursuant to the requirements of the Master Indenture of Trust, dated as of April 1, 1998 (the “Master Indenture”), between the Issuer and Wells Fargo Bank, N.A., as trustee (the “Trustee”), as amended and supplemented, including by the Twenty-First Supplemental Indenture of Trust, dated as of the Closing Date (the “Twenty-First Supplemental Indenture,” and together with the Master Indenture as previously amended and supplemented, the “Indenture”), between the Issuer and the Trustee, substantially in the forms previously delivered to the Purchaser. Capitalized terms used but not defined herein have the meanings set forth in the Private Placement Agreement, dated September 28, 2016 (the “Private Placement Agreement”), between the Issuer and the Purchasers.

The Purchasers hereby make the following representations and warranties to the Issuer in connection with the Purchasers’ purchase of the Bonds:

1. The Purchasers have sufficient knowledge and experience in financial and business matters, including purchase and ownership of municipal tax-exempt and taxable obligations to be able to evaluate the risks and merits represented by the purchase of the Bonds.
2. The Purchasers have authority to purchase the Bonds and to execute this letter and any other instruments and documents required to be executed by the Purchasers in connection with the purchase of the Bonds.
3. GSUIG Real Estate Member LLC is a [] organized under the laws of [] and is able to bear the economic risks of purchasing the Bonds and Calvert Social Investment Foundation, Inc. is a [] organized under the laws of [] and is able to bear the economic risks of purchasing the Bonds

4. The Purchasers understand that the Bonds are secured in the manner set forth in the Indenture and have received and reviewed to their satisfaction a copy of the Indenture.

5. The Purchasers understand (a) the circumstances under which, time at which and amount in which the Issuer may be obligated to pay the Purchasers an Outcome Payment and the unsecured nature of any such payment obligation, and (b) the circumstances under which, time at which and amount in which the Purchasers may be obligated to pay the Issuer a Risk Share Payment, and the means by which such payment would be effected.

6. The Purchasers understand that an official statement, prospectus, offering circular, offering memorandum or other comprehensive offering statement has not been provided with respect to the Bonds and that, as of the date hereof, there is no existing or future obligation on the part of the Issuer to provide information of the sort included in the documents described in this sentence. The Purchasers have made its own independent investigation of the facts and circumstances surrounding the Issuer, the System and the Bonds and is not relying on the Issuer, its agents or its employees with respect to the sufficiency and scope of such investigation. The Purchasers are relying upon the accuracy of the representations and warranties of the Issuer made in the Private Placement Agreement.

7. The Purchasers acknowledge that they have has reviewed information, including financial statements and other financial information, regarding the Issuer and the System, and have had the opportunity to ask questions and receive answers from knowledgeable individuals concerning the Issuer, the System, the Bonds and the security therefor, so that they have been able to make an informed decision to purchase the Bonds; provided, however, that this letter shall not constitute a waiver of any rights or remedies the Purchasers may have with respect to (a) any untrue information it may have received or (b) any misconduct or fraud on the part of representatives of the Issuer resulting in a failure to provide requested information for review by the Purchasers.

8. The Bonds are being acquired by the Purchasers for their own account, respectively, and not with a present view toward resale, transfer or distribution; provided, however, that the Purchasers reserve the right to sell, transfer or distribute the Bonds, but agrees that any such sale, transfer or distribution by the Purchasers shall be subject to the restrictions set forth in the Indenture or the Private Placement Agreement.

9. The provisions of the Private Placement Agreement, the Indenture and this letter are not, and should not be deemed to be, dispositive of the character of the debt for any legal, accounting or regulatory purposes.

Dated September 29, 2016

GSUIG REAL ESTATE MEMBER LLC

By: _____
Name: Margaret Anadu
Title: Authorized Signatory

**CALVERT SOCIAL INVESTMENT
FOUNDATION, INC.**

By: _____
Name: Catherine Godschalk
Title: Vice President, Investments

[Signature Page of Purchasers Acknowledgement Letter]

EXHIBIT C
Request for Proposal
Design-Build Services for Green Infrastructure,
Rock Creek Project A (Division RC-A)
Contract No: 150210 dated July 1, 2016

EXHIBIT D

Technical Memorandum

DISTRICT OF COLUMBIA
WATER AND SEWER AUTHORITY

DC CLEAN RIVERS PROJECT

**ENVIRONMENTAL IMPACT BOND
TECHNICAL EVALUATION MEMORANDUM
FINAL**

September 13, 2016

Prepared for:



Prepared by:



Program Consultants Organization
Blue Plains Advanced Wastewater Treatment Plant
5000 Overlook Avenue, SW
Washington, DC 20032

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1 Introduction

1.1 Purpose

The purpose of this document is to describe the approach used to collect data, establish a methodology, and develop tools used to evaluate the effectiveness of Rock Creek Project 1 (“RC-A”) as part of the DC Clean Rivers Project (DCCR). An Environmental Impact Bond (EIB) is proposed to raise capital for the project. The methodology described has been used to make baseline predictions for the runoff reductions due to RC-A green infrastructure (GI) installations and establishes an approach for evaluation of actual reductions after the GI is constructed.

1.2 Environmental Impact Bond

The EIB will finance the design, construction and maintenance of RC-A which is required to manage the volume of runoff produced by 1.2” of rain falling on 20 impervious acres in the Rock Creek sewershed. Through the EIB, the Issuer and Purchaser intend to develop a pay-for-success model to achieve certain environmental outcomes associated with GI. In doing so, the EIB is structured to pay a variable total rate of return dependent upon the effectiveness of GI to manage stormwater runoff in RC-A. Greater efficacy may result in an Outcome Payment to the Purchaser that increases the total rate of return on the EIB, and lesser efficacy may result in a Risk Sharing Payment to DC Water that reduces the total rate of return on the EIB.

1.3 DC Clean Rivers Project

The District of Columbia Water and Sewer Authority (DC Water) is implementing a LTCP to control combined sewer overflows (CSOs) to the District of Columbia’s (District) waterways. DCCR is comprised of a variety of projects to control CSOs, including pumping station rehabilitations, targeted sewer separation, GI, and a system of underground storage/conveyance tunnels. DCCR is being implemented in accordance with a first amendment to the Consent Decree (Amended Consent Decree), entered on January 14, 2016, which amends and supersedes the 2005 Consent Decree (Consent Decree) and incorporates GI, in a hybrid green-gray solution, to control CSOs while improving the quality of life in the District.

1.4 Rock Creek Green Infrastructure Project RC-A

The Rock Creek sewershed is comprised of 2,329 total acres, of which 52% is impervious (1,215 impervious acres). In an average year, the CSO 049 outfall structure, which drains the Rock Creek sewershed, discharges 39.73 million gallons of combined sewage to Rock Creek. Table 1-1 summarizes the Rock Creek sewershed area characteristics for CSO 049.

Table 1-1. Rock Creek Sewershed Area

	CSO 049
Total Sewershed Area	2,329 acres
Impervious Area	1,215 acres
Impervious Area to be Managed	365 acres

Source: DC Water (2016).

As part of the Amended Consent Decree, GI will be constructed in the CSO 049 drainage area in Rock Creek, sized to manage the volume of runoff produced by 1.2" of rain falling on 365 impervious acres (30% of the impervious acres) in the sewershed. GI controls will be constructed to manage the stormwater volume required in the Amended Consent Decree primarily in the public right-of way (ROW), allowing for some implementation on publicly-owned land outside of the ROW and on private property.

The first Rock Creek GI project is located along the eastern edge of the Rock Creek GI Area, shown on Figure 1-1, and includes approximately 162 acres. This project boundary was selected for the following reasons:

- Feasibility of design and construction
- Availability and feasibility of monitoring locations
- Representative land use characteristics typical of Rock Creek GI Area

The project area is mostly residential in nature, comprised of 55 city blocks of row houses mostly within the Brightwood Park and Manor Park neighborhoods of northwest Washington, DC. The project area is bounded by Oglethorpe Street NW and Gallatin Street NW to the north and south, respectively, and 1st Street NE and 3rd Place NW to the east and west, respectively. Existing conditions data has been collected (i.e., topographic survey information) from which the surface characteristics of the sewershed were defined and refined.

The GI control measures used within RC-A include bioretention and permeable pavement in the ROW and downspout disconnection on private properties. Bioretention facilities collect runoff in shallow, vegetated depressions. They then filter and temporarily store the runoff before allowing it to infiltrate into in-situ soils or conveying it to a suitable outlet (such as an existing sewer or stormwater pipe). Permeable pavement systems will be used to replace (or in lieu of) traditional impervious pavements as they offer similar functionality with respect to vehicle and pedestrian traffic. Facilities will include perforated underdrains tied to the existing underground sewer infrastructure.

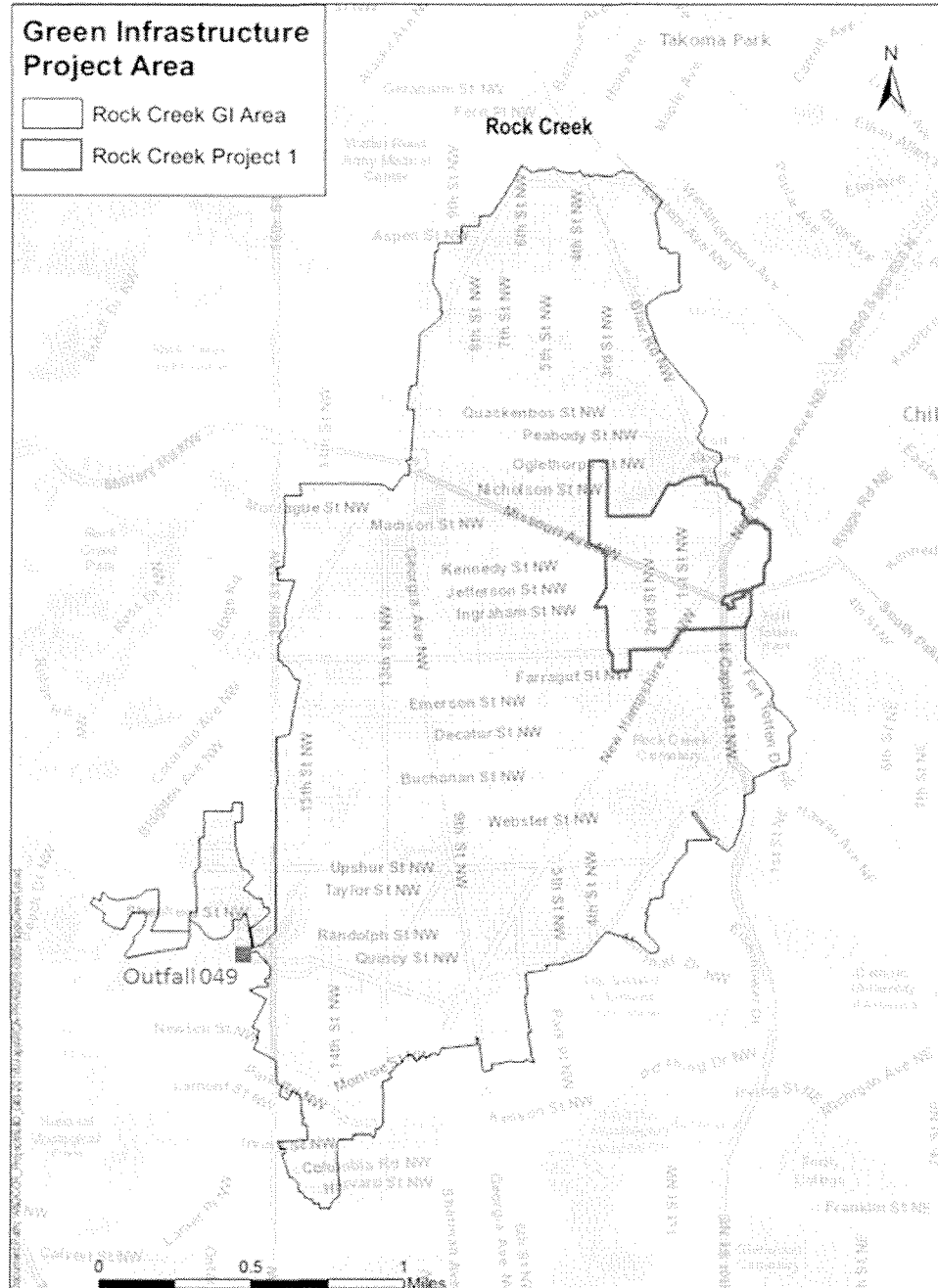


Figure 1-1. Rock Creek GI Area and Rock Creek Project A

2 Analysis Approach

2.1 Pre-construction Monitoring

The runoff quantities for existing conditions will be determined prior to the installation of GI control measures in RC-A. The pre-construction monitoring program requires installation of a rain gauge and flow measuring devices at predetermined locations at each project site (see Figure 2-2). Pre-construction monitoring will be performed over a 12-month period. During this 12-month period, available collection system meter data will be gathered to estimate the sanitary portion of the dry weather flow, and groundwater elevations at monitoring wells will be recorded to evaluate the relationship to infiltration. A portion of the monitoring has been completed and has been used to establish baseline runoff projections. Pre-construction monitoring is a necessary step to ground-truth the runoff model to real-world observations and will be used in model calibration.

Given the schedule for the bond, only a portion of the preconstruction monitoring has been completed and a subset of the anticipated 12 months of data has been used to prepare this report.

2.1.1 Rain Gages

One tipping bucket rain gage was installed within the RC-A area to capture local rainfall. The meter is located at Washington Latin School, as shown in Figure 2-1.

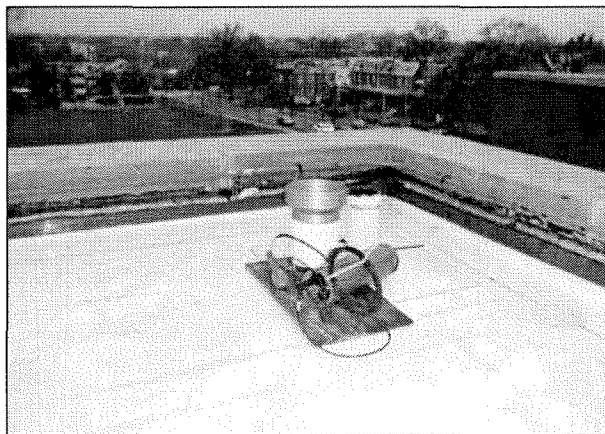


Figure 2-1. RC-A Rain Gage at Washington Latin School

2.1.2 Flow Meters

Four flow meters were installed within the RC-A project area. The flow meters are area-velocity meters that are used to measure mean velocity in a pipe and measure depth of flow in the pipe. The sensor transmits a continuous ultrasonic wave, then measures the frequency shift of returned echoes reflected by air bubbles or particles in the flow. The meters produce instantaneous depth-averaged velocity and flow depth, and records data every 5 minutes. Flow rate is calculated using velocity and depth (as measured by the meter), and pipe shape information. Flow meters are located as shown in Figure 2-2.

Flow meters must be calibrated to on-site conditions. Meters are visited regularly and at any point where review of data suggests that a calibration is in order. Flow depth and velocity are calibrated to replicate observed conditions at the site of the meter during the calibration.

Flow meter locations were selected to capture runoff from a variety of pre- and post-construction locations. Table 2-1 describes the flow meter purposes and drainage area to each meter. Site reports for the meters are located in Appendix A.

Table 2-1. RC-A Flow Meters

Meter	Purpose	Drainage Area (ac)
RC-A 049-1	Quantify total runoff reduction from RC-A	103
RC-A 049-2	Quantify total runoff reduction from RC-A	19
RC-A 049-3	Monitor runoff from a specific group of GI practices	0.9
RC-A 049-4	Monitor runoff from a specific group of GI practices	1.2

2.1.3 Groundwater Monitoring

For the RC-A project, seven groundwater monitoring wells have been installed, which will be monitored for a period of one year. Throughout field investigations, observations have been reported regarding groundwater, infiltration, obstructing layers, and soil classification to provide information critical for design. Groundwater monitoring wells are typically placed at a depth of seven feet with a five foot screen. They are visited monthly for inspection and data collection. A typical well installation diagram is shown in Appendix B.

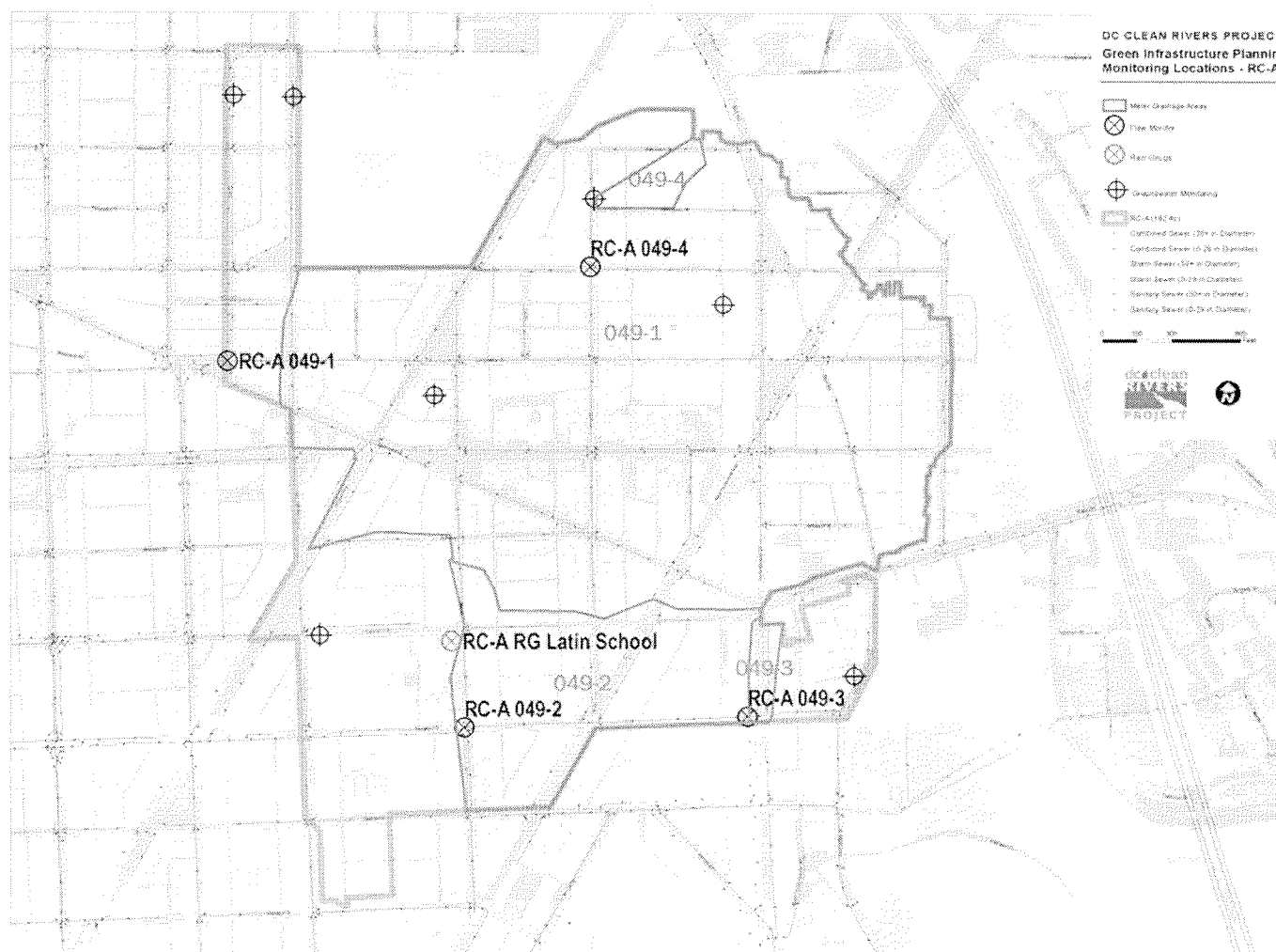


Figure 2-2. Pre- and Post-Construction Monitoring Locations for Rock Creek Project A

Source: DCCR

2.2 Definition of Average Rainfall Year

EPA's CSO Control Policy (1994) requires the effectiveness of CSO controls to be evaluated on a "system-wide, annual average basis." Identification of annual average rainfall conditions is thus a fundamental step in the LTCP process. Once selected, the average rainfall conditions will become the basis for modeling the sewer system and receiving waters to evaluate the occurrence of CSOs, their impact on receiving waters, and the efficacy of CSO controls.

Historical rainfall records from various gages in and around the District of Columbia were reviewed. The most comprehensive and useful records were those from Ronald Reagan Washington National Airport, which is located on the western bank of the Potomac in Virginia, approximately 3 miles from the White House and downtown Washington, DC. Continuous hourly records are available for 50 years at this location from 1949 to 1998. Due to the availability of continuous hourly data, this gage was used as the basis for establishing existing rainfall conditions.

The rainfall characteristics of individual years and groups of successive years were compared to the annual average rainfall statistics for the 50-year period of record. In particular, 3-year periods were singled out and reviewed favorably since they offer a broader range of rainfall events than a single year, while allowing for reasonable computational time for modeling. Based on the evaluation, the single year 1990 and the 3-year period 1988 to 1990 were identified as representative of annual average conditions. Because of the robust number and variety of storms available in a 3-year period, as opposed to a 1-year period, the period 1988 to 1990 was used as the average rainfall condition that will be used for modeling to support development of the LTCP. The rainfall that occurred during 1988 to 1990 will serve as the basis for evaluating the occurrence and impact of CSOs, and the efficacy of controls on a "system-wide, annual average basis."

The rainfall characteristics of 1988 to 1990 are compared against the long-term average rainfall characteristics in Table 2-2.

Table 2-2. Rainfall Statistics

Statistic	Long Term Average ¹	Average of 1988-1990
Annual Rainfall (inches)	38.95	40.97
No. Events > 0.05 inches	74	71
Average Storm Duration (Hours) ²	9.9	10.1
Average Maximum Intensity (in/hr)	0.15	0.16
Maximum Intensity (in/hr)	1.30	1.29

¹ Ronald Reagan Washington National Airport hourly data, 1949-1998

² Individual events separated by a minimum of 6 hours with no rain

2.3 Model Development

2.3.1 Model Scope

A continuous hydrologic runoff model was developed to simulate runoff under existing, pre-GI conditions and to estimate the runoff reduction expected under future conditions with GI implemented. The runoff model is an application of the EPA SWMM5 model. SWMM5 is the current

version of the most widely applied urban stormwater model across the world. Recent extensions of SWMM5 include specific GI applications. EPA's long-term support to the development and application of SWMM5 and earlier SWMM models underscores its acceptance in applications to support regulatory programs. SWMM5 is the model used for the range of GI-related modeling for the DCCR.

The model includes subcatchments representing runoff in the RC-A project area, the sewer network conveying the flow to the outlets of the RC-A project area and the GI practices planned for RC-A.

2.3.2 Model Calibration

Based on the metering data collected, the RC-A model was calibrated to predict runoff and flow from the sewershed. The model calibration is summarized in Section 3.

2.3.3 Representation of GI

GI practices are represented in SWMM5 as "LID controls." SWMM5 is a lumped parameter model that assumes uniformity across a single modeled sewershed. This means that LID controls were designed to represent the total of all GI practices contained within the modeled sewershed instead of representing each GI practice separately. This is common practice in a lumped parameter model and appropriate for this resolution of model. GI practices in SWMM5 are grouped into bioretention and pervious pavement based on their general design and purpose. Based on the planned GI design for RC-A, and delineated drainage to each type of planned GI practice, flow is routed to the appropriate practice on an area-weighted basis. Practices are represented in SWMM5 based on contract design drawings. In SWMM5, runoff from the surface to be treated by an LID control is routed to the control before entering the sewer system. Runoff not entering an LID control flows directly to the hydraulic model. SWMM5 represents LID controls as shown in Figure 2-3. All LID controls use the same framework, with runoff entering the LID through the surface layer and passing to other layers or out of the LID control through evapotranspiration (ET), overflow, underdrain, or infiltration based on parameters defined for each GI practice.

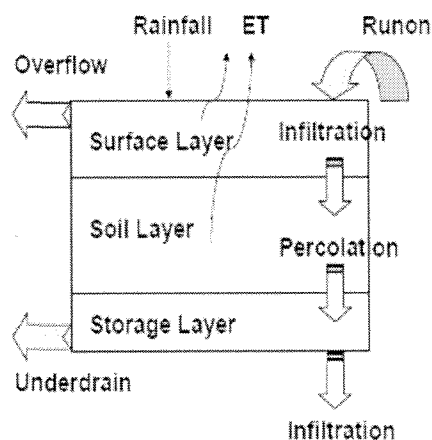


Figure 2-3. SWMM5 LID Control Representation

Infiltration from each of the LID controls into the underlying soil is assumed to occur at a rate equal to the Horton method minimum infiltration rate for the subwatershed within which it is contained. This is a conservative assumption and accounts for probable soil compaction under the LID control. Soil infiltration is a parameter that was varied and analyzed under the sensitivity analysis described below. Each LID control has a simulated underdrain represented as presented in the design documents. Underdrain outflow is assumed to flow directly into the collection system.

2.4 Calculation of Stormwater Runoff Volume

2.4.1 Event Descriptions

CSOs are caused by peak flows exceeding the diversion or treatment capacity of the system. Wet weather events were therefore defined as the time period when predicted flows in the sewer exceeded two times average dry weather flow rates. The value of two times dry weather flow was selected because it is the original basis of design for the complete treatment capacity of the Blue Plains Advanced Wastewater Treatment Plant in the *Blue Plains Feasibility Study* (Final Report, 1984, Greeley and Hansen). Further, it is a common factor used to differentiate flow regimes in the sanitary engineering industry. Figure 2-4 illustrates the approach utilized.

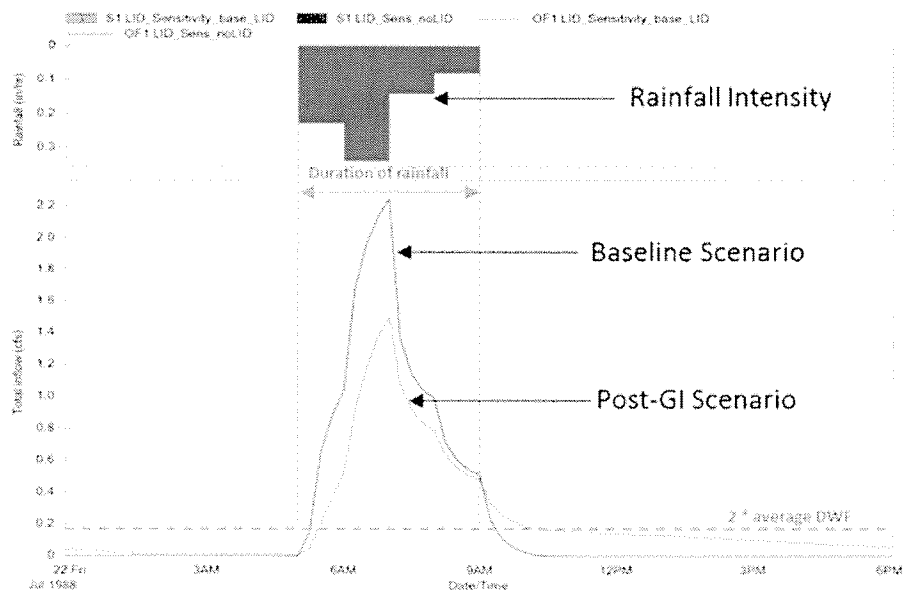


Figure 2-4. Stormwater Runoff Event Definition

2.4.2 Methodology

Several model simulations will be used to develop the predicted runoff reduction and actual runoff reduction expected from the RC-A project.

2.4.2.1 Existing Conditions

The existing conditions model uses the identical model application that was calibrated as described above. The model is applied for the 1988-1990 average year period to predict flow vs. time for the RC-A area. The total volume of flow, including runoff and dry-weather flow, as measured at meters

RCA-049-1 and RCA-049-2 (see Figure 2-2), and restricted to wet-weather event periods (as described above) for 1988-1990 is the total Existing Condition Runoff measured in gallons per average year. This forms a baseline from which to measure runoff reductions expected under GI implementation.

Stormwater runoff is calculated as all flow greater than twice the long-term average dry weather flow.

2.4.2.2 Predicted Conditions after Green Infrastructure

The model was used to predict the annual average runoff reduction expected under GI implementation. GI was represented in the model as described above. This is a prediction based on our best representation of the planned GI and is not a calibrated model. This is meant to be our best prediction of the planned runoff volume reduction expected if GI is implemented as planned.

The difference between the Predicted Conditions and Existing Conditions annual average runoff yields the Predicted Runoff Reduction.

Three scenarios were simulated to bracket the accepted range of expected results:

- **Best Case:** GI performs at the high end of accepted parameters. This is the predicted results if, for example, soil is highly permeable, soil media has high conductivity, and void ratio of media is high.
- **Expected Case:** GI performs as indicated in design drawings and using average assumptions for parameters not specified in the design.
- **Worst Case:** GI performs at the low end of accepted parameters. This is the predicted results if, for example, soil is less permeable, soil media has a low conductivity, and void ratios are low.

Table 2-3 shows the SWMM GI coefficients that are used in the expected case scenario and the basis for selecting these coefficients.

Table 2-3: SWMM GI Parameterization for Expected Case Scenario

		Description	Curb Extention Bioretention	Planter Bioretention	Permeable Alley	Permeable Pavement in Parking Lane	Basis
Surface	Storage Depth (in)	Depth of surface storage	6.96	6.96	0.1	0.1	Design
	Vegetated Volume (frac)	Space occupied by vegetation	0	0	0	0	Accepted Value
	Surface Roughness (n)	Manning's roughness	0.1	0.1	0.1	0.1	Accepted Value
Pavement	Surface Slope	Surface Slope	0	0	0.026	0.035	Design
	Thickness (in)	Pavement thickness	-	-	6	5	Design
	Void Ratio	Pavement void ratio	-	-	0.2	0.2	Accepted Value
	Imp. Surface Fraction	Used for modular systems	-	-	0	0	Design
	Permeability	Permeability rate	-	-	100	100	Accepted Value
	Clogging Factor	Pavement clogging	-	-	949	656	Assume ~10% annual clogging
Soil	Thickness (in)	Media thickness	24	24	-	-	Design
	Porosity (frac)	Porosity	0.33	0.33	-	-	Design
	Field Capacity (frac)	Green and Ampt soil parameter	0.1	0.1	-	-	Accepted Value
	Wilting Point (frac)	Green and Ampt soil parameter	0.05	0.05	-	-	Accepted Value
	Conductivity (in/hr)	Media design conductivity	1	1	-	-	Design
	Conductivity Slope	Green and Ampt soil parameter	7	7	-	-	Accepted Value
	Suction Head (in)	Green and Ampt soil parameter	1.4	1.4	-	-	Accepted Value
Storage	Height (in)	Storage depth	21	21	36	37	Design
	Void Ratio	Void ratio	0.67	0.67	0.67	0.67	Design
	Infiltration (in/hr)	Bottom infiltration rate	0.125	0.125	0.125	0.125	Calibrated
	Clogging Factor	Bottom clogging	217	561	53	45	Assume ~10% clogging per year
Drain	Drain Coeff (in/hr)	Non-linear coefficient	0.18	0.18	0.18	0.20	Design
	Drain Exponent	Non-linear coefficient	0.50	0.50	0.50	0.50	Design
	Drain Offset (in)	Height of drain from bottom	3	3	3	3	Design

Of the listed parameters, the following parameters were identified as highly sensitive and were varied in the best and worst case scenario:

- Soil Porosity
- Soil Infiltration Capacity
- Storage Void Ratio
- Storage Bottom Infiltration

While the Storage Clogging Factor is identified as a sensitive model parameter, it was not varied as part of the sensitivity analysis. The Storage Clogging Factor is set to a value that reflects approximately 10% clogging in one year of service. While this is a sensitive parameter, proper maintenance of GI practices, as required by contract, gives confidence in setting this parameter constant.

Model coefficients that define GI were varied between minimum and maximum expected ranges, based on literature values and the RC-A GI design documents, and the resulting expected difference in average annual runoff reported in Section 4. The range of sensitive values used is shown in Table 2-4.

Table 2-4: Range of Sensitive Values Evaluated

	Best Case	Base Case	Worst Case
Curb Extension and Planter Bioretention			
Soil Porosity (frac)	0.45	0.33	0.15
Soil Infiltration Capacity (in/hr)	1.8	1	0.6
Storage Void Ratio (frac)	0.8	0.67	0.6
Storage Bottom Infiltration (in/hr)	1.8	0.125	0.02
Permeable Pavement in Parking Lane and Alley			
Storage Void Ratio (frac)	0.8	0.67	0.6
Storage Bottom Infiltration (in/hr)	1.8	0.125	0.01

Soil porosity varies from the minimum and maximum soil porosity expected due to variabilities in installation, supply, and inherent soil conditions. Soil infiltration capacity varies from the minimum to maximum soil infiltration capacity (or wet conductivity) that can be expected from a bioengineered soil media. The storage void ratio (defined as porosity / (1-porosity)) varies based on expected variance caused by installation and handling. The storage bottom infiltration is the native soil infiltration rate. Local infiltration tests have shown infiltration rates much higher than indicated here. 1.8 in/hour was selected as the best case because it matches the soil infiltration capacity. Any rate higher than the soil infiltration capacity will not be fully utilized as runoff will be restricted in the soil layer before reaching the storage layer.

The DCCR GI design includes a rapid draining system that routes ponded flow directly to the storage layer of the practice. This was not explicitly represented in the SWMM model. For the evaluation time period of 1988-1990, rainfall and runoff are not intense enough to regularly utilize the rapid draining system. As a result, not modeling this practice does not have a significant impact on annual wet weather volume managed. The practice can have an impact on the number of CSO events during short duration intense rain events and it is for that reason that it was included in the design.

2.4.2.3 Actual Conditions after Green Infrastructure

Following GI construction and post-construction flow monitoring, the predicted conditions model will be calibrated to flow monitoring data. Flow meters will be placed in the same locations as pre-construction monitoring. The annual average runoff will be calculated as was done for the previous scenarios. The difference between the actual conditions and predicted conditions for annual average runoff yields the deviation between predicted and actual runoff. The final report will present these results.

2.4.3 Sensitivity Analysis

There are several sources of uncertainty inherent in hydrologic and hydraulic modeling. The model is a representation of real-world conditions and can only be as accurate as the data used to create it. This model will depend on spatial elevation data, sewer data, and GI designs. Additionally, there are inherent errors when translating real-world conditions to the model representation. Hydrologic processes such as infiltration and evaporation use empirical formulas developed over years of study, but still are simply a representation of what is happening. These inherent errors make calibration necessary to build confidence in a model.

This model will be calibrated to the pre-construction flow monitoring to represent existing conditions. The Predicted Conditions model is a forecast model that will not be calibrated, but will rely on our best representations of the predicted GI. In order to evaluate the sensitivity of annual runoff to changes in model parameters, a sensitivity analysis will be performed.

A basic sensitivity analysis was performed by identifying the best and worst case parameters for 4 sensitive parameters as described in Section 2.4.2.2. These values are used as a guide to predict the expected range of runoff reduction cause by GI implementation.

Building on this analysis, a Monte Carlo simulation was developed. In a Monte Carlo simulation, ranges of values are used for a number of inputs. The model is run many times using combinations of input data from within the acceptable ranges. Model results for average annual runoff reduction will fall within a range as determined by the Monte Carlo simulation. This will provide an interval of confidence in the model results and highlight what parameters have a high influence on the variation of average annual runoff.

The SWMM variables identified for sensitivity were randomly sampled using either a normal or log-normal distribution as indicated, and each set of randomly sampled sensitivity parameters were used as inputs for 1000 sequential SWMM model simulations. The resulting simulated runoff reduction is reported as a distribution of values.

The parameters shown in Table 2-5 were identified as sensitivity parameters earlier in our analysis, and shown are the assumption used in developing the Monte Carlo analysis. The standard deviations were chosen to capture the minimum and maximum values expected to be encountered for the parameter listed. All other SWMM parameters were held at the values described in Section 2.4.2.2.

The variance in parameters is based on the variance calculated in the best case and worst case analysis. Some parameter ranges may differ slightly due to the inherent properties of the statistical distribution. A normal distribution requires that the 95th percentile confidence interval be centered on the mean.

Table 2-5: Monte Carlo Simulation Parameters

	Monte Carlo Simulation			
	Highest 95%-ile	Mean	Lowest 95%-ile	Distribution
Curb Extension and Planter Bioretention				
Soil Porosity (frac)	0.47	0.33	0.19	Normal
Soil Infiltration Capacity (in/hr)	1.6	1	0.4	Normal
Storage Void Ratio (frac)	0.77	0.67	0.57	Normal
Storage Bottom Infiltration (in/hr)	1.8	0.125	0.02	Log-Normal
Permeable Pavement in Parking Lane and Alley				
Storage Void Ratio (frac)	0.77	0.67	0.57	Normal
Storage Bottom Infiltration (in/hr)	1.8	0.125	0.02	Log-Normal

3 Pre-Construction Calibration

3.1 Calibration Period

Flow and rainfall monitoring data were available for a time frame of January 22nd, 2016 until June 2nd, 2016. However flow monitoring data for January and February was determined to unreliable for calibration purposes and also includes 2 significant snowfall events. Therefore the model calibration time period chosen was March 1st, 2016 through June 2nd, 2016.

All rainfall events were used in the calibration except those which were not expected to produce a flow meter response similar to the average-year climate period, which this model will be applied to. The following are examples of events that are typically excluded from calibration:

- Events that produce runoff that exceeds the capacity of the sewer system
- Events that produce snow accumulation
- Events that occur when metering or rain gage equipment is out-of-service or requires maintenance
- Events that occur during repairs to the sewer system or where damage to the sewer system has occurred

3.2 Rainfall

The rain gage used for this project was installed at the corner of Ingraham Street and 2nd Street, NE (see Figure 2-2). A total sum of 8.14 inches of total rainfall was observed during the calibration period.

The rainfall data was compared to another local rainfall gage close-by and determined to be consistent (difference of 7% in total rainfall volume).

There were 19 rainfall events with a total rainfall depth > 0.1 inch and a minimum inter-event time (dry time) of 3 hours which were used for the model calibration as shown in Table 3-1.

Table 3-1: Observed Rainfall Events

Event #	Start Date / Time	Duration (h)	Max Rain (in/hr)	Mean Rain (in/hr)	Total Rain (in)
1	3/2/2016 0:25	4.83	0.12	0.03931	0.19
2	3/13/2016 20:05	10.5	0.24	0.03524	0.37
3	3/19/2016 12:20	10.5	0.12	0.02667	0.28
4	3/28/2016 0:00	10.08	0.24	0.02876	0.29
5	4/7/2016 7:10	5.67	0.96	0.1094	0.62
6	4/7/2016 16:45	2.92	0.72	0.08914	0.26
7	4/9/2016 5:25	7.67	0.12	0.01696	0.13
8	4/28/2016 8:35	5.75	0.24	0.04696	0.27
9	4/30/2016 21:55	15.5	0.36	0.04581	0.71
10	5/2/2016 18:40	4.75	1.2	0.1305	0.62
11	5/3/2016 20:50	6.58	0.36	0.02734	0.18
12	5/6/2016 5:55	13.5	0.12	0.05037	0.68
13	5/11/2016 12:15	6.08	0.12	0.02301	0.14
14	5/14/2016 15:25	3.33	0.24	0.042	0.14
15	5/17/2016 8:40	11.17	0.12	0.02866	0.32
16	5/21/2016 5:40	5.5	0.48	0.08909	0.49
17	5/21/2016 23:35	31.58	0.24	0.01266	0.4
18	5/23/2016 15:00	5.5	0.12	0.02909	0.16
19	5/29/2016 17:00	7.75	0.96	0.07871	0.61

3.3 Flow Monitoring

Flow monitoring in the RC-A area was done in 4 locations as shown on Figure 2-2. Only Meters RC-A 049-1 and RC-A 049-2 (which are the 2 downstream meters) were used for this calibration due to their location. Meter RC-A 049-1 covers an area of about 103 acres and meter RC-A 049-2 an area of about 19 acres.

Meter results were quality checked and considered of an adequate quality. Meter RC-A 049-1 provides usable data throughout the whole calibration period. Meter RC-A 049-2 had a meter outage from April 12th to May 11th due to problems with both the depth and the velocity sensor.

A dry-weather flow analysis showed an average dry-weather flow (DWF) of 0.25 MGD for meter RC-A 049-1 and 0.08 MGD for meter RC-A 049-2. Dry weather flow patterns (diurnal curves) have been developed based on the available metering data individually for both meter sheds (see Figure 3-1 and Figure 3-2).

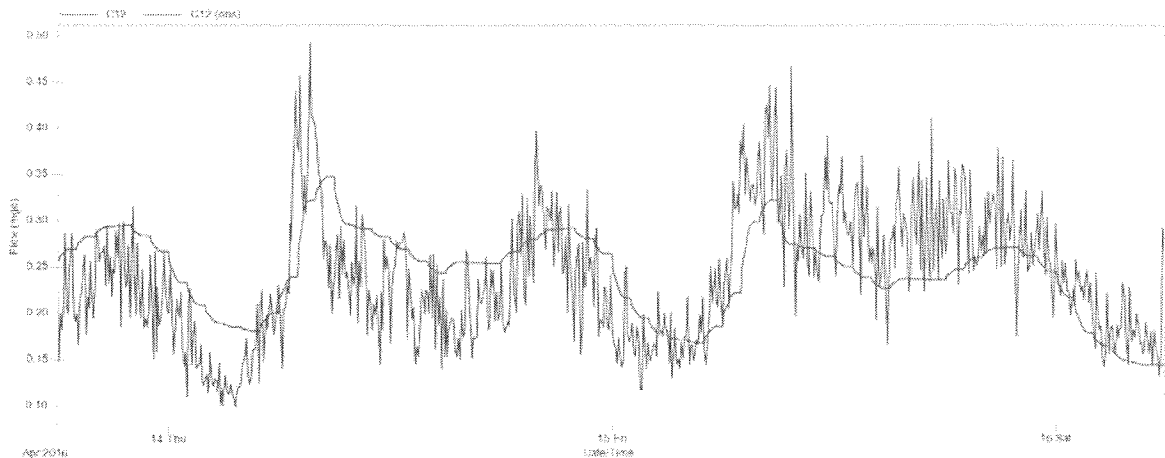


Figure 3-1: Model - data comparison for DWF at meter location RC-A 049-1

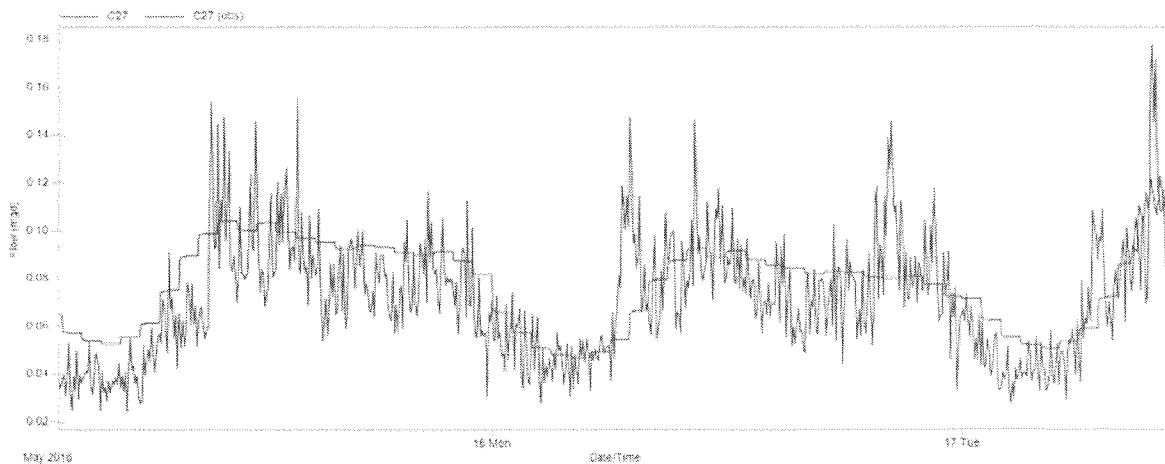


Figure 3-2: Model - data comparison for DWF at meter location RC-A 049-2

The highest observed wet weather flow is 31.03 MGD for RC-A 049-1 and 2.04 MGD for RC-A 049-2 during the chosen calibration period. The total observed Wet Weather Flow (WWF) volume for RC-A 049-1 during the calibration period was 4.85 MG and 0.74 MG (estimated due to partial meter outage) at RC-A 049-2.

3.4 Calibration Methodology

The model was setup using the available data basis and supplemented by textbook values appropriate for the conditions of the RC-A model area.

Based on field surveys, it was estimated that 11% of impervious area within RC-A is attributed to rooftops that were disconnected from the combined sewer system. These rooftops were modeled as impervious area draining to pervious area. The remaining rooftop area was assumed to drain to the combined sewer system.

The runoff model was then calibrated to match the volume, flow peak and general shape of the wet weather flow events. This was done within the PC-SWMM environment using visual hydrograph comparisons for individual wet weather events (general shape) as well statistical comparisons using 1:1 plots (linear regression (R squared) and Nash-Sutcliffe model efficiency coefficient (NSE)). PC-SWMM is an interface of the EPA SWMM5 model engine that provides pre-processing, post-processing, and data analysis tools. The parameters chosen for calibration are shown below in Table 3-2.

Table 3-2: Runoff Parameter Calibration

Parameter	Basis	Calibration parameter
Area of subshed (ac)	Calculated based on GIS	NO
Width of subshed (ft)	Calculated based on GIS	YES (within accepted range)
Slope (%)	Calculated based on GIS	YES (within accepted range)
Imperviousness (%)	Calculated based on GIS and decreased by disconnected roof top area	NO
Impervious area roughness	Textbook value	YES (within accepted range)
Pervious area roughness	Textbook value	YES (within accepted range)
Depression storage Impervious area (in)	Textbook value	YES (within accepted range)
Depression storage Pervious area (in)	Textbook value	YES (within accepted range)
No depression storage for Impervious area (%)	Textbook value	YES (within accepted range)
Maximum Infiltration Rate (in/hr)	Textbook value based on SSUGRO HSG	YES (within accepted range)
Minimum Infiltration Rate (in/hr)	Textbook value based on SSUGRO HSG	YES (within accepted range)
Decay Constant (1/hr)	Textbook value	NO
Drying Time (days)	Textbook value	NO

The parameter with the biggest impact on the calibration was the selected soil infiltration rate. The SSUGRO (Soil Survey Geographic database) which was used for the initial parameterization shows the majority of the RC-A model area within HSG (hydrologic soil group) class D (dense soils with low infiltration capacity and high runoff potential) but was then later recalibrated to an approximately equivalent of an HSG class B soil (soils with medium density and moderately low runoff potential). This was still deemed within an accepted range based on local soil boring infiltration tests.

3.5 Calibration Results

The model was calibrated at meter locations RC-A 049-1 and verified at RC-A 049-2 for the wet weather events outlined in

Table 3-1. Meter events 8 - 12 were excluded from the analysis for RC-A 049-2 due to a meter outage during that time. Calibration plots for meter RC-A 049-1 are shown in Figure 3-3 through Figure 3-8 below.

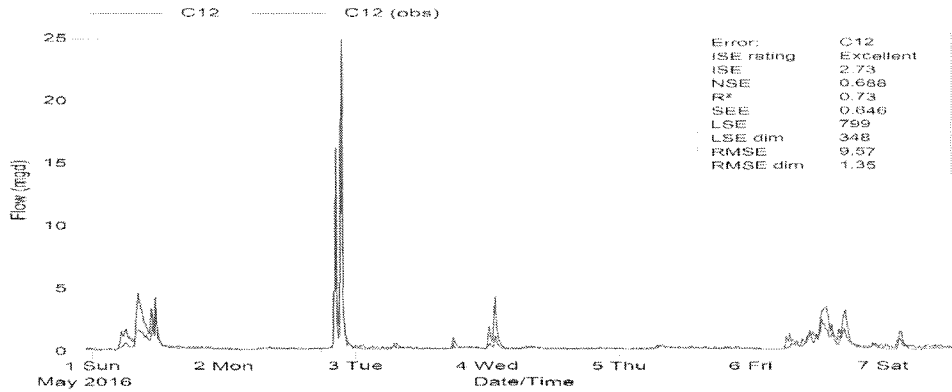


Figure 3-3: Example hydrograph comparison at meter RC-A 049-1

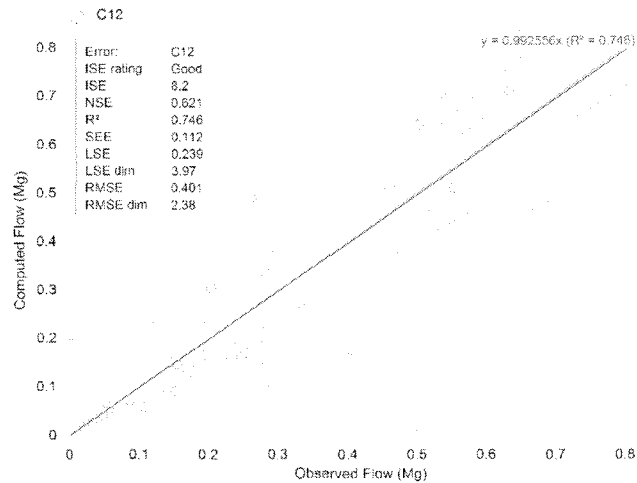


Figure 3-4: 1-1 Plot comparison for wet weather event flow volumes at meter RC-A 049-1

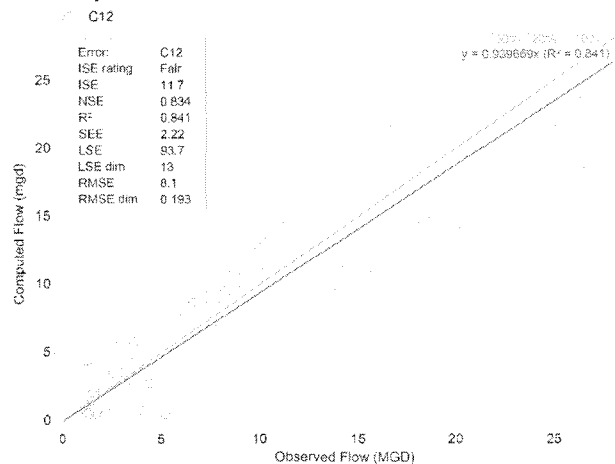


Figure 3-5: 1-1 Plot comparison for wet weather event peak flows at meter RC-A 049-1

Calibration plots for meter RC-A 049-2 are shown in Figure 3-6 to Figure 3-8 below.

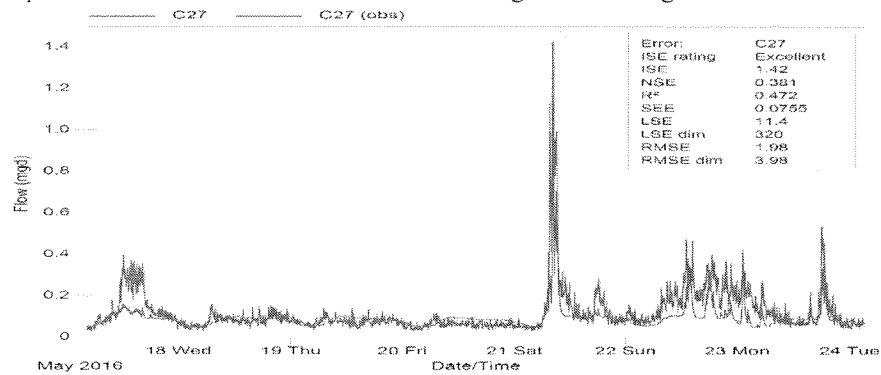


Figure 3-6: Example hydrograph comparison at meter RC-A 049-2

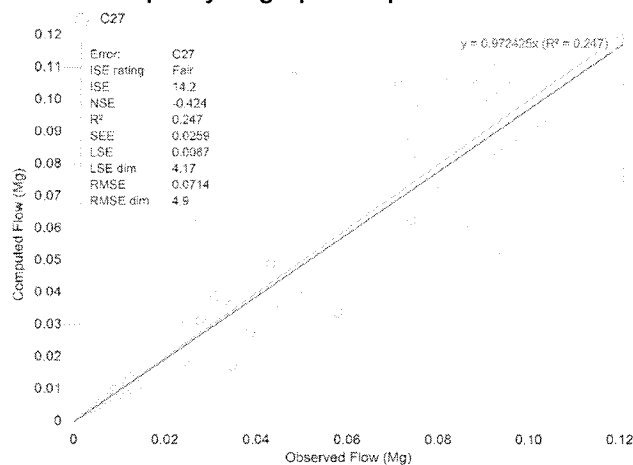


Figure 3-7: 1-1 Plot comparison for wet weather event flow volumes at meter RC-A 049-2

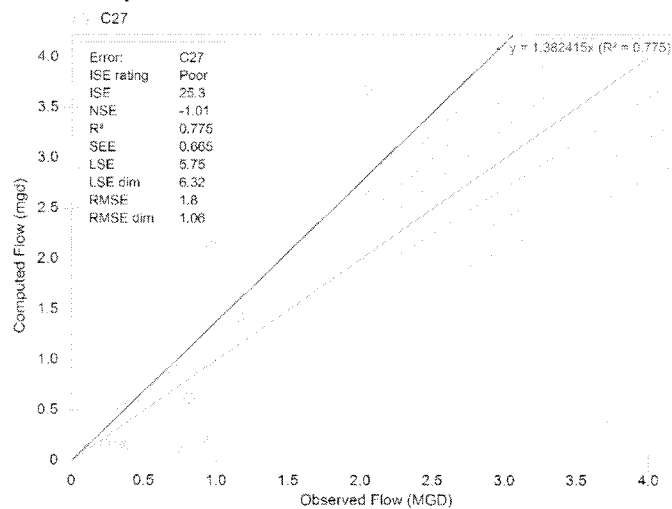


Figure 3-8: 1-1 Plot comparison for wet weather event peak flows at meter RC-A 049-2

4 Post-Construction Predictions

4.1 Predicted Runoff Reduction

The GI parametrization described in Section 2 was applied to the calibrated model, resulting in a model meant to forecast runoff reduction after GI installation occurs.

Three scenarios were simulated to bracket the accepted range of expected results:

- Best Case: GI performs at the high end of accepted parameters. This is the predicted result if, for example, soil is highly permeable, soil media has high conductivity, and void ratio of media is high.
- Expected Case: GI performs as indicated in design drawings and using average assumptions for parameters not specified in the design.
- Worst Case: GI performs at the low end of accepted parameters. This is the predicted result if, for example, soil is less permeable, soil media has a low conductivity, and void ratios are low.

Table 4-1 shows predicted results from the three model simulations.

Table 4-1: Wet Weather Flow for 1988-1990 (MG/average year)

	RC-A-49-1		RC-A-49-2		Combined	
	WW flow (MG)	reduction	WW flow (MG)	reduction	WW flow (MG)	reduction
NO LID	37.06	---	6.58	---	43.65	---
LID best case	23.52	36.54%	2.85	56.66%	26.38	39.57%
LID base	26.81	27.66%	3.77	42.69%	30.59	29.93%
LID worst case	30.70	17.18%	4.51	31.46%	35.21	19.33%

The LID best case and LID worst case were compared to the confidence interval evaluation below to confirm the results of that process.

4.2 Sensitivity Analysis Results

The results of the Monte Carlo analysis are shown below.

Table 4-2 shows the annual wet weather flow calculated with LID in place. Table 4-3 shows the annual wet weather flow normalized to impervious acre treated at 1.2". Normalization was performed because the quantity of GI actually constructed may vary somewhat from the as-designed plans due to utility conflicts or other modifications to the facilities that may be required during construction to accommodate actual conditions encountered in the field.

The frequency distribution of the 1000 SWMM model simulations is shown in Figure 4-1 and Figure 4-2.

Table 4-2: Annual Wet-Weather Flow (MG/average year)

		Meter RC-A-49-1	Meter RC-A-49-2	Total	Percent Reduction
LID	No LID	37.06	6.58	43.65	
	95th Percentile	24.53	3.29	27.82	36.3%
	Mean	26.77	3.71	30.47	30.2%
	5th Percentil	29.25	4.09	33.33	23.6%

Table 4-3: Annual Avg. WWF Reduction (MG/avg. year per Impervious Acre Treated at 1.2")

	Meter RC-A-49-1	Meter RC-A-49-2	Total	Percent Reduction	Range
95th Percentile	0.75	0.63	0.72	36.3%	13%
Mean	0.61	0.55	0.60	30.2%	
5th Percentile	0.47	0.48	0.47	23.6%	

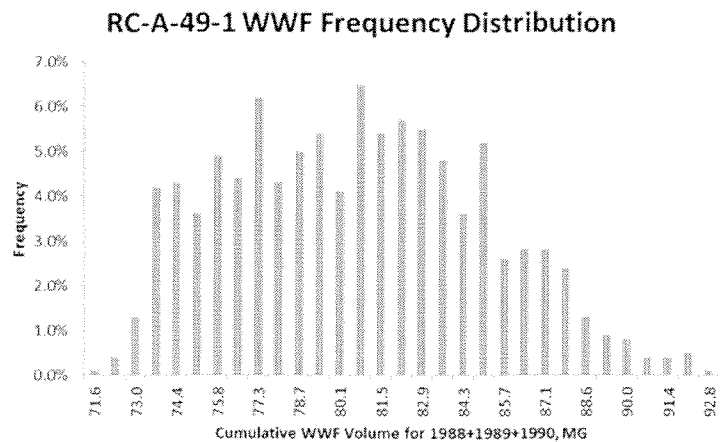


Figure 4-1: RC-A-49-1 Wet Weather Flow Frequency Distribution

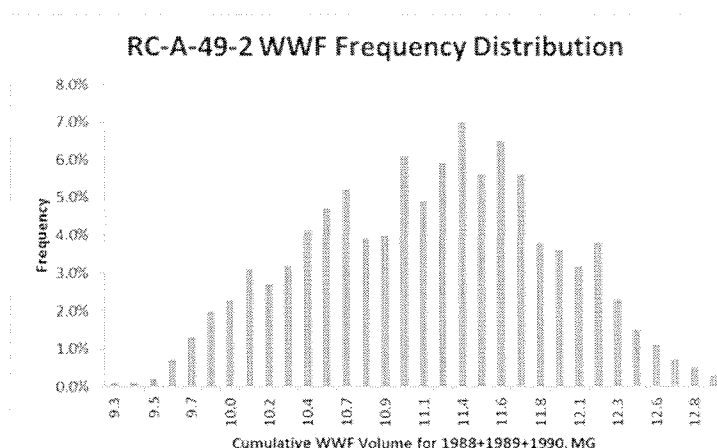


Figure 4-2: RC-A-49-2 Wet Weather Flow Frequency Distribution

The confidence interval analysis varied the four parameters listed in Section 2. In order to account for variation in the other SWMM parameters that are not accounted for in the Monte Carlo analysis, a factor of 5% was added to the 95th percentile runoff reduction results and a factor of 5% was subtracted from the 5th percentile runoff reduction results. This additional factor was based on DC Water's engineering judgment regarding the overall accuracy of data collection, modeling, and the ability to make predictions of this nature. These adjusted results are shown in Table 4-4 and these results are the recommended ranges to use for the 5th and 95th percentile ranges.

Table 4-4: Adjusted Annual Avg. WWF Reduction (MG/Impervious Acre Treated at 1.2")

	Percent Reduction	Range
Adjusted 95 th Percentile	41.3%	} 23%
Adjusted 5 th Percentile	18.6%	

Note: Reference Table 4-3 for values (mean, 95th percentile, and 5th percentile) prior to adjustment

4.3 Approach to Evaluation Post-Construction Data

Following GI construction and post-construction monitoring, the same methodology presented will be used to quantify the actual post-construction runoff reduction achieved with GI installed. The following summarizes the approach to quantifying WWF reduction after construction:

- Post-construction monitoring will be performed for 12 months and will consist of the following:
 - A rain gage will be installed in the sewer shed and flow meters will be installed in the existing sewers. The equipment will be installed at the same locations used for pre-construction monitoring unless this is infeasible for some reason. In that case, equipment will be installed as close as is practical to the pre-construction locations.
 - Groundwater elevations will be monitored at wells installed prior to construction to assess overall groundwater levels
- The GI in the model will be configured to represent as-built conditions.

- The model will be run for the post construction monitoring period rainfall and will be calibrated to the flow meter data collected.
- After the model is calibrated, it will be run using the rainfall in the average year period (1988-1990) to predict the WWF volume in an average year defined as occurring when predicted flows in the sewer exceeded two times average dry weather flow rates as described in this memorandum.
- The reduction in WWF volume per average year will be calculated by taking the difference between the pre- and post-construction WWF volume. This reduction in WWF volume will be divided by the number of impervious acres treated at 1.2" to determine the WWF reduction in million gallon per average year per impervious acre treated at 1.2". The resulting percent reduction in WWF will be computed and compared to the pre-construction predicted range.

Appendix A Flow Meter Installation Reports

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Site Name/Manhole # 049-1

Primary: ☒ Alternate: ☐

Investigation Date: 12/15/15 Time: 13:40 Crew Members: CL/MH

Installation Date: 12/29/15 Time: 13:15 Crew Members: CL/MM

Address/Location: Intersection of Longfellow Street NW and 3rd Place NW

Latitude: N 38°57' 28" Longitude: W 77°1' 1"

Weather Conditions: Wet Dry**Hydraulic Conditions****Influent Flow:**Velocity 2.70 ft/secDepth 1.50 in**Turbulence Amplitude:**☐ Less than 0.25"☒ 0.25" to 0.75"☐ 0.75" to 1.5"☐ 1.5" to 3"☐ Greater than 3"**Sewer Line Characteristics:**

	Influent 1	Influent 2	Influent 3	Effluent
Height	4' 3"	12"	15"	4' 3"
Width	4' 3"	12"	15"	4' 3"
Material	Concrete	Concrete	Concrete	Concrete
Shape	Round	Round	Round	Round

Sediment Present:

☐ Yes Hard packed: _____ in. deep
☒ No Soft: _____ in. deep

Surcharge / Backwater Influence:☒ No evidence visible☐ Remains in pipe☐ _____ ft from rim☐ Reaches Rim (potential meter damage)☐ Evidence unclear: _____ ft from rim**Gas Investigation:**☐ Good 20.9 (condition)**Site Conditions****Site Access:**☐ Good (no problems accessing site)☒ Fair (minor traffic control, truck accessible off-road site, can safely carry equipment to site)☐ Poor (remote areas, steel embankments, No safe place to park, elevated MH >3 ft)☐ Traffic Control only (Requires extra traffic control)☐ Unusable (Document in Comments section)**Manhole Information:**Elevated Manhole: ☐ Yes ☒ No

Height above ground _____

Manhole depth 13' 9"

Structural Integrity of Manhole:

☐ Good ☒ Fair ☐ Poor**Pipe Bends:** *None within camera view*☐ Influent ☐ Effluent ☐ Manhole

Approx Distance to bend: _____ ft

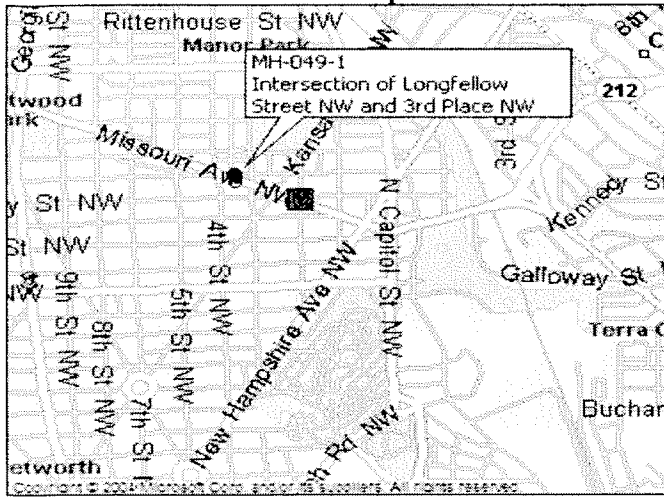
Pipe Size/Geometry/Material Change:☐ Influent ☐ Effluent ☐ ManholeApprox Distance to change: _____ ft
(detail is comments)**Crew Member:** Can you maintain this site?☒ Yes ☐ No ☐ Maybe**Sensor Configuration:**

(Please include Serial Numbers when possible)

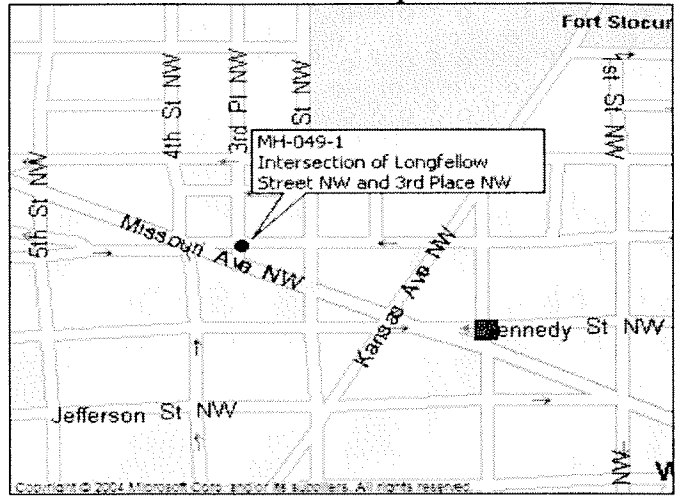
Level	Primary: Flowav
	Redundant:
Velocity	Primary: Flowav
	Redundant:
Meter Logger	Telog

Comments:

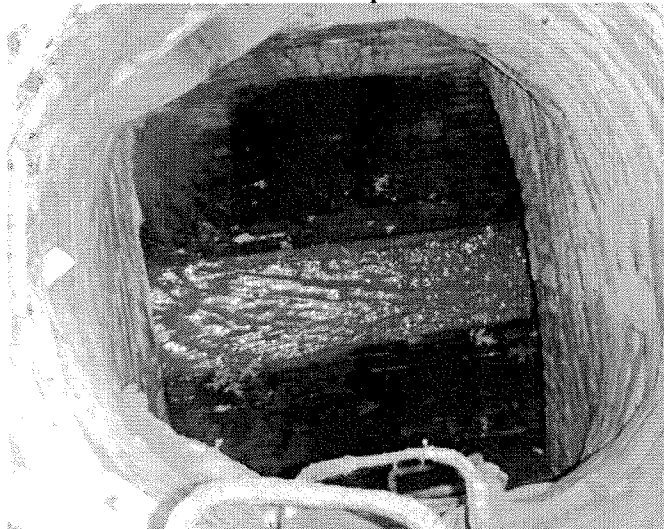
Area Map



Detail Map



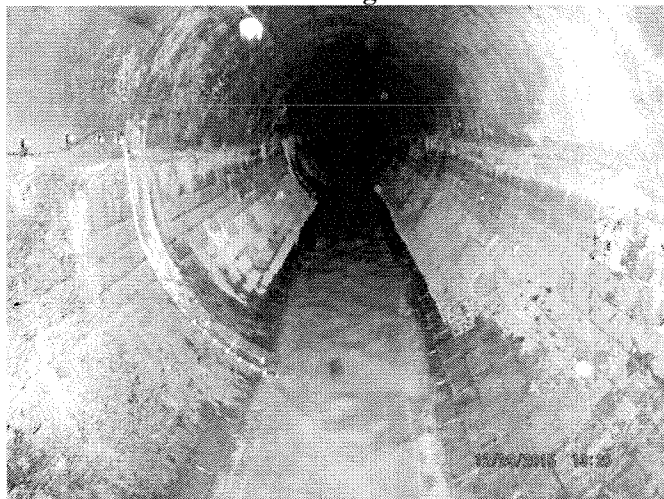
View from top of MH



Site Overview



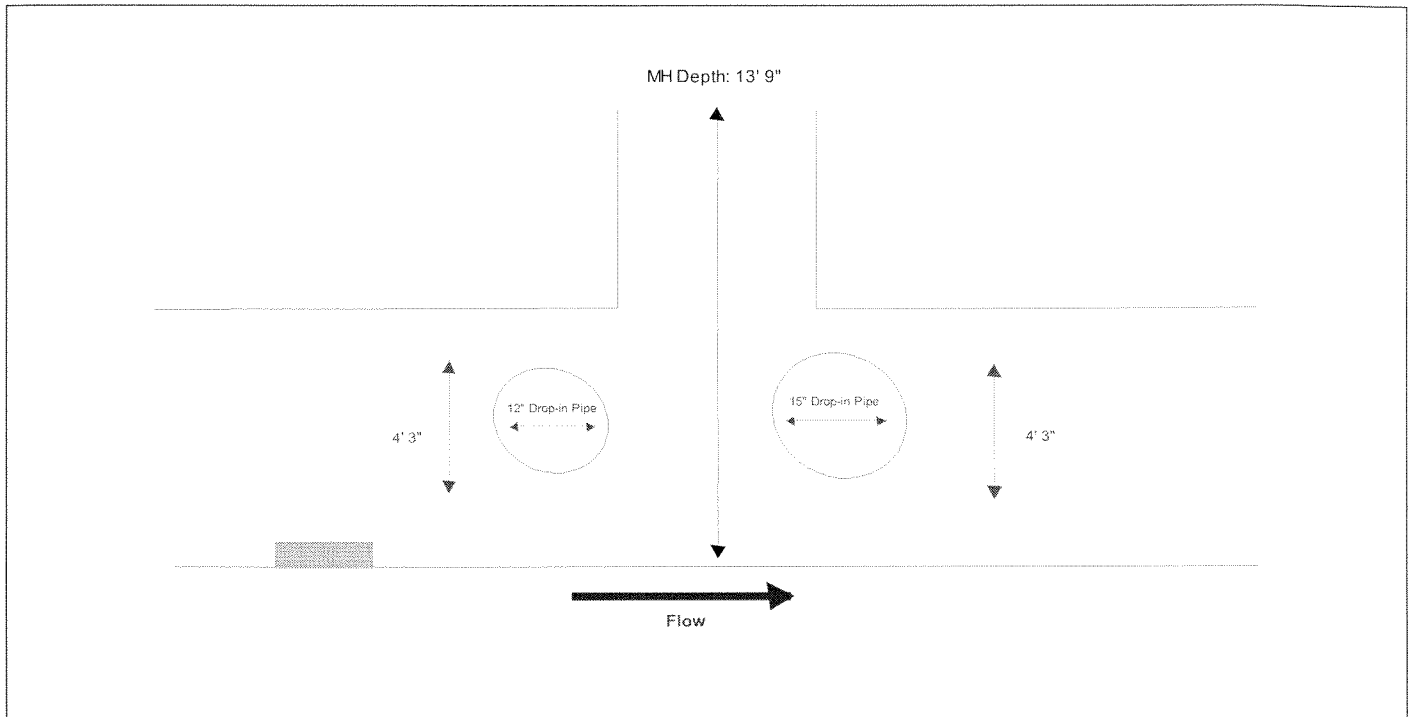
View of flow through influent line



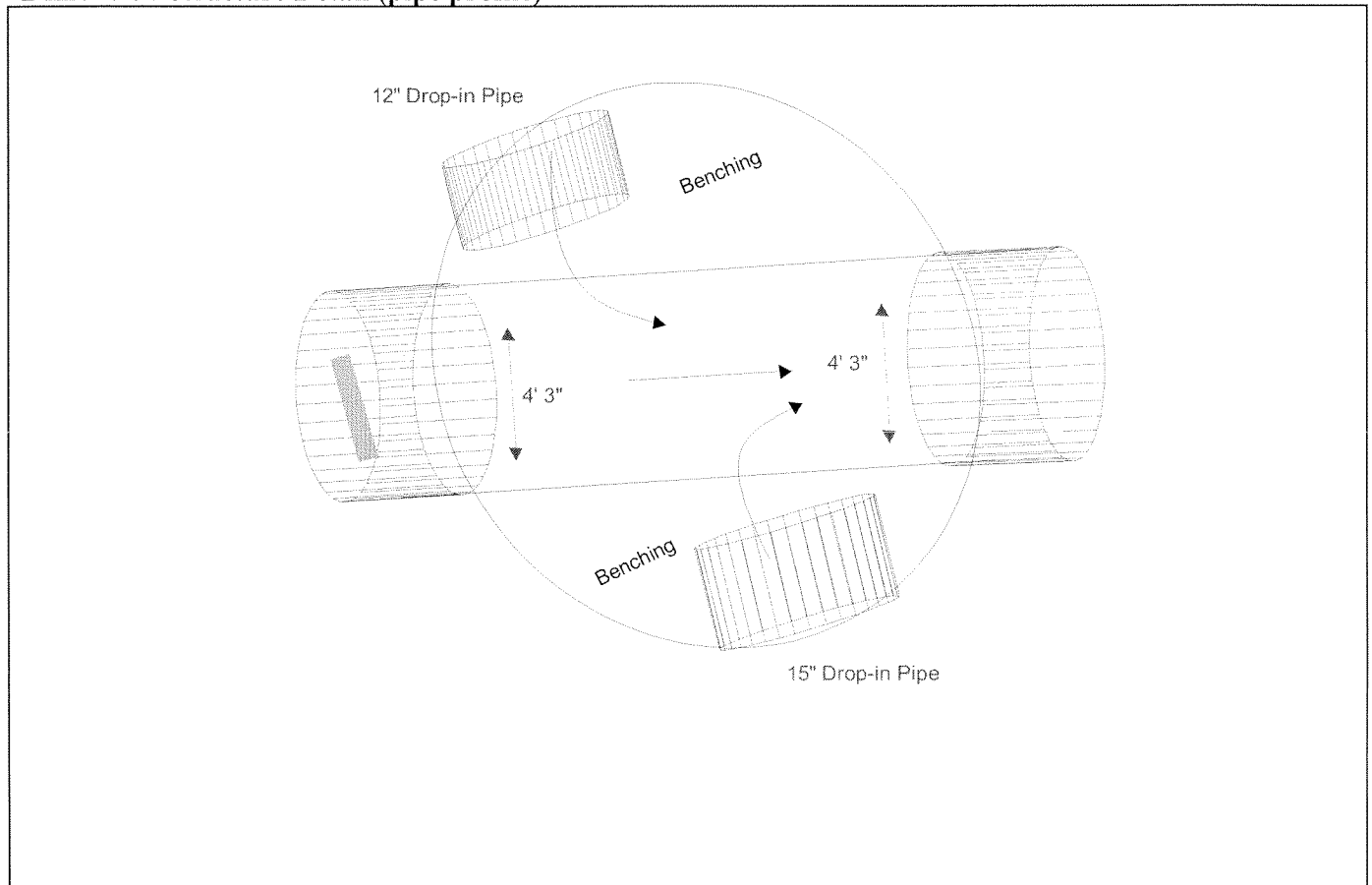
View of flow through effluent line



Dimensional Structure Profile View (profile sketch showing location of sensors)



Dimension Structure Detail (pipe profile)



Sketch or plat showing upstream and downstream manholes, connections, and bends.



Site Name/Manhole # 049-2

Primary: ☒ Alternate: ☐

Investigation Date: 12/16/15 Time: 7:40 Crew Members: CL/MH

Installation Date: 12/29/15 Time: 15:30 Crew Members: CL/MM

Address/Location: Intersection of Hamilton Street NW and 2nd Street NW

Latitude: N 38°57'11.9" Longitude: W 77°00' 48.7"

Weather Conditions: Wet Dry



Hydraulic Conditions

Influent Flow:

Velocity 1.50 ft/sec

Depth 1.25 in

Turbulence Amplitude:

☐ Less than 0.25"

☒ 0.25" to 0.75"

☐ 0.75" to 1.5"

☐ 1.5" to 3"

☐ Greater than 3"

Sewer Line Characteristics: Inf. #6: 15" Dry Pipe at top

	Infl 1	Infl 2	Infl 3	Infl 4	Infl 5	Effluent
Height	24.75"	18"	15"	12"	15"	36"
Width	24.75"	18"	15"	12"	15"	24"
Material	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete
Shape	Round	Round	Round	Round	Round	Oval

Sediment Present:

☐ Yes Hard packed: _____ in. deep
☒ No Soft: _____ in. deep

Surcharge / Backwater Influence:

☒ No evidence visible

☐ Remains in pipe

☐ _____ ft from rim

☐ Reaches Rim (potential meter damage)

☐ Evidence unclear: _____ ft from rim

Gas Investigation:

☐ Good 20.9 (condition)

Site Conditions

Site Access: Not during rush hour traffic hours

☐ Good (no problems accessing site)

☒ Fair (minor traffic control, truck accessible off-road site, can safely carry equipment to site)

☐ Poor (remote areas, steel embankments, No safe place to park, elevated MH >3 ft)

☐ Traffic Control only (Requires extra traffic control)

☐ Unusable (Document in Comments section)

Manhole Information:

Elevated Manhole: ☐ Yes ☒ No

Height above ground _____

Manhole depth 13' 10"

Structural Integrity of Manhole:

☐ Good ☒ Fair ☐ Poor

Pipe Bends: None within camera view

☐ Influent ☐ Effluent ☐ Manhole

Approx Distance to bend: _____ ft

Pipe Size/Geometry/Material Change:

☒ Influent ☐ Effluent ☐ Manhole

Approx Distance to change: _____ ft
 (detail is comments)

Crew Member: Can you maintain this site?

☒ Yes ☐ No ☐ Maybe

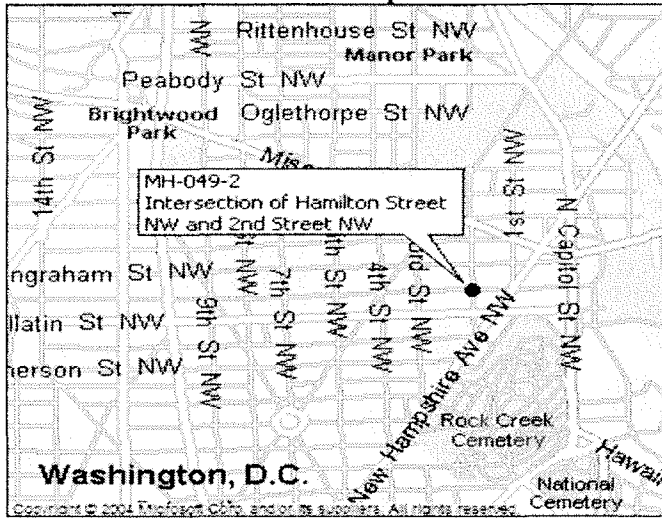
Sensor Configuration:

(Please include Serial Numbers when possible)

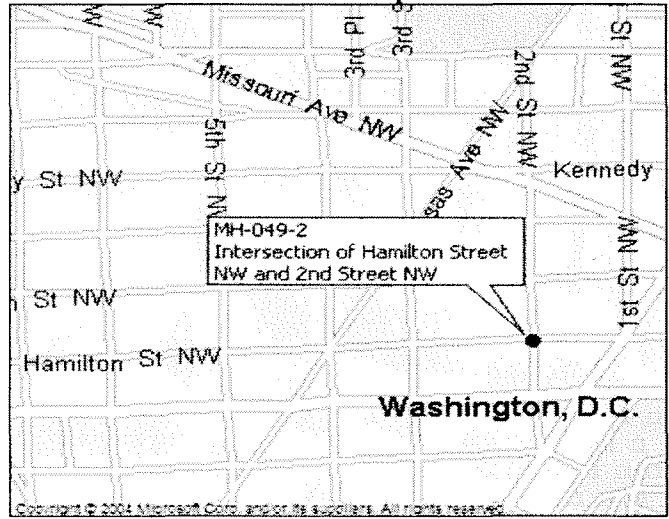
Level	Primary: Flowav
	Redundant:
Velocity	Primary: Flowav
	Redundant:
Meter Logger	Telog

Comments:

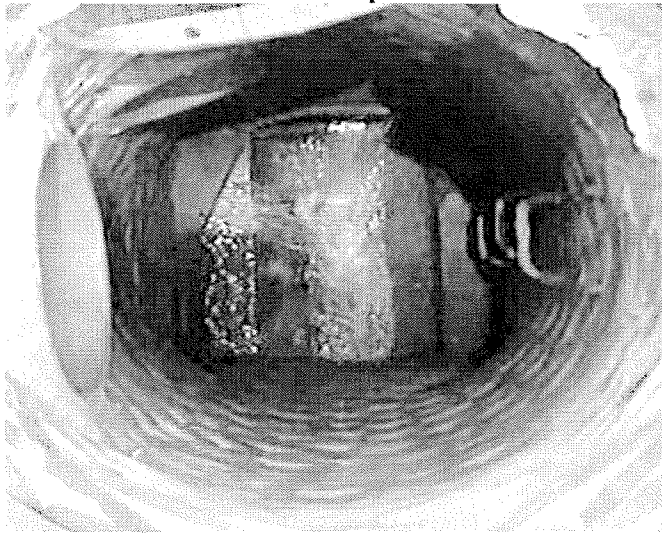
Area Map



Detail Map



View from top of MH



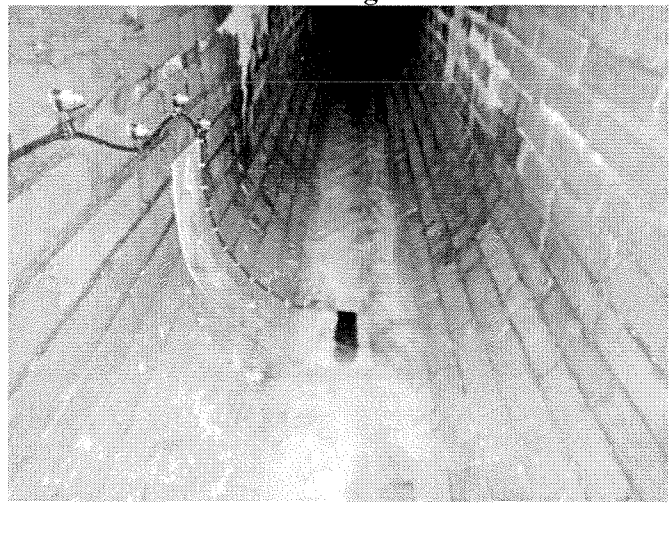
Site Overview



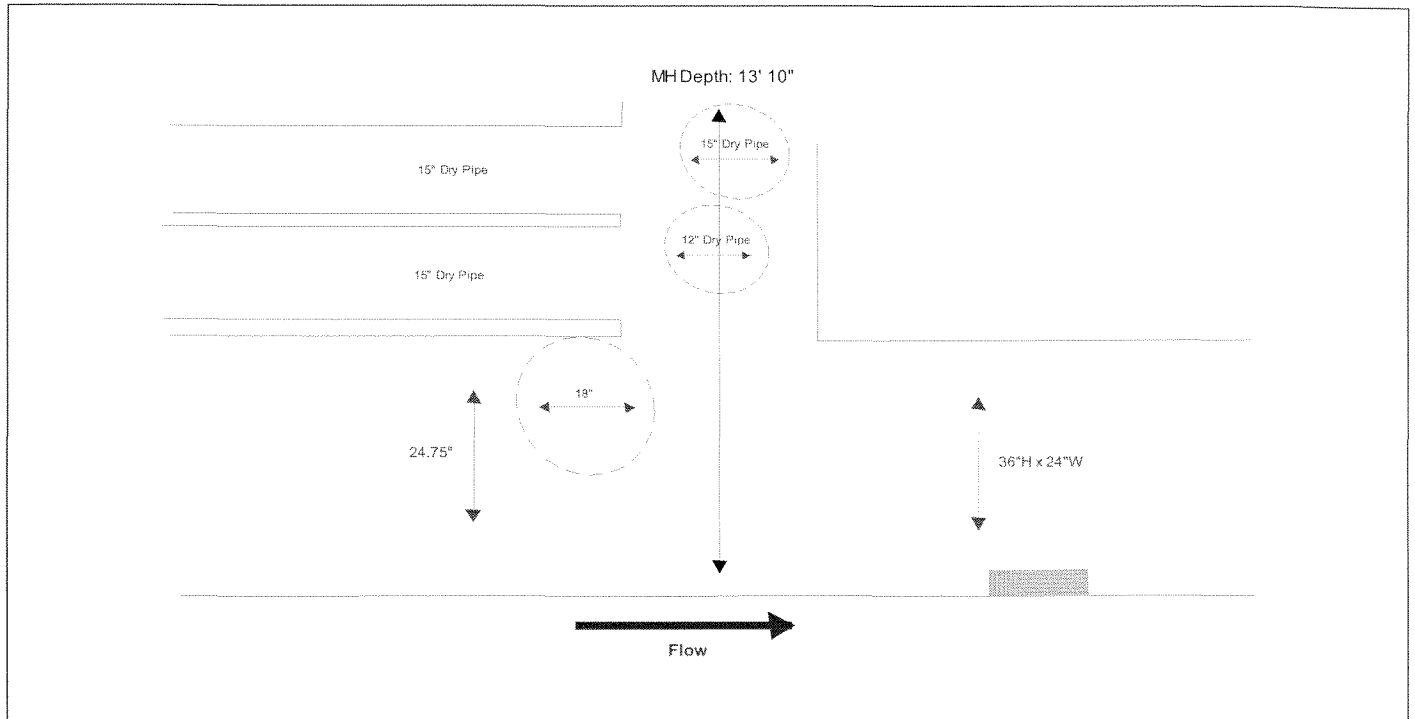
View of flow through influent line



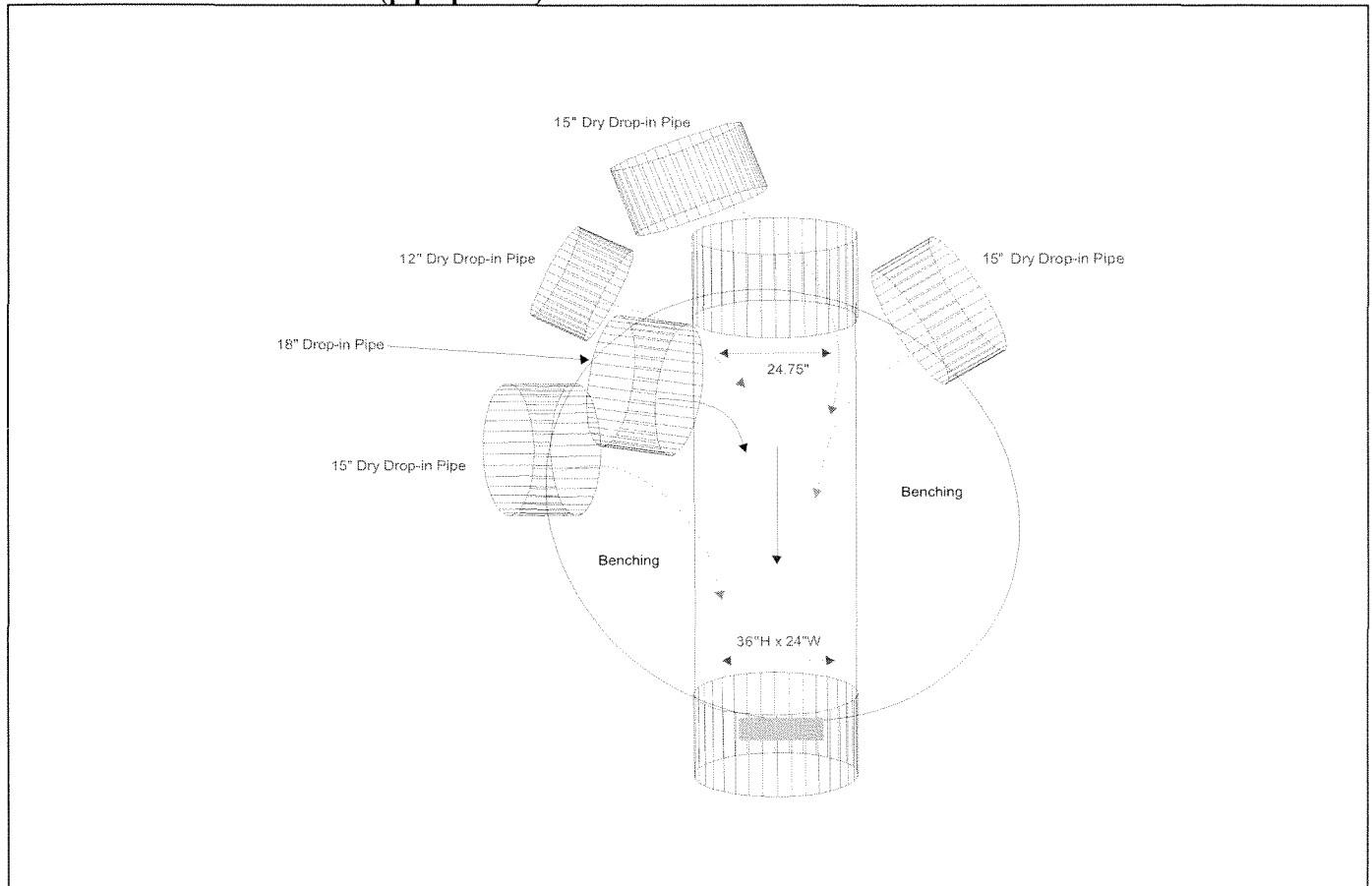
View of flow through effluent line



Dimensional Structure Profile View (profile sketch showing location of sensors)

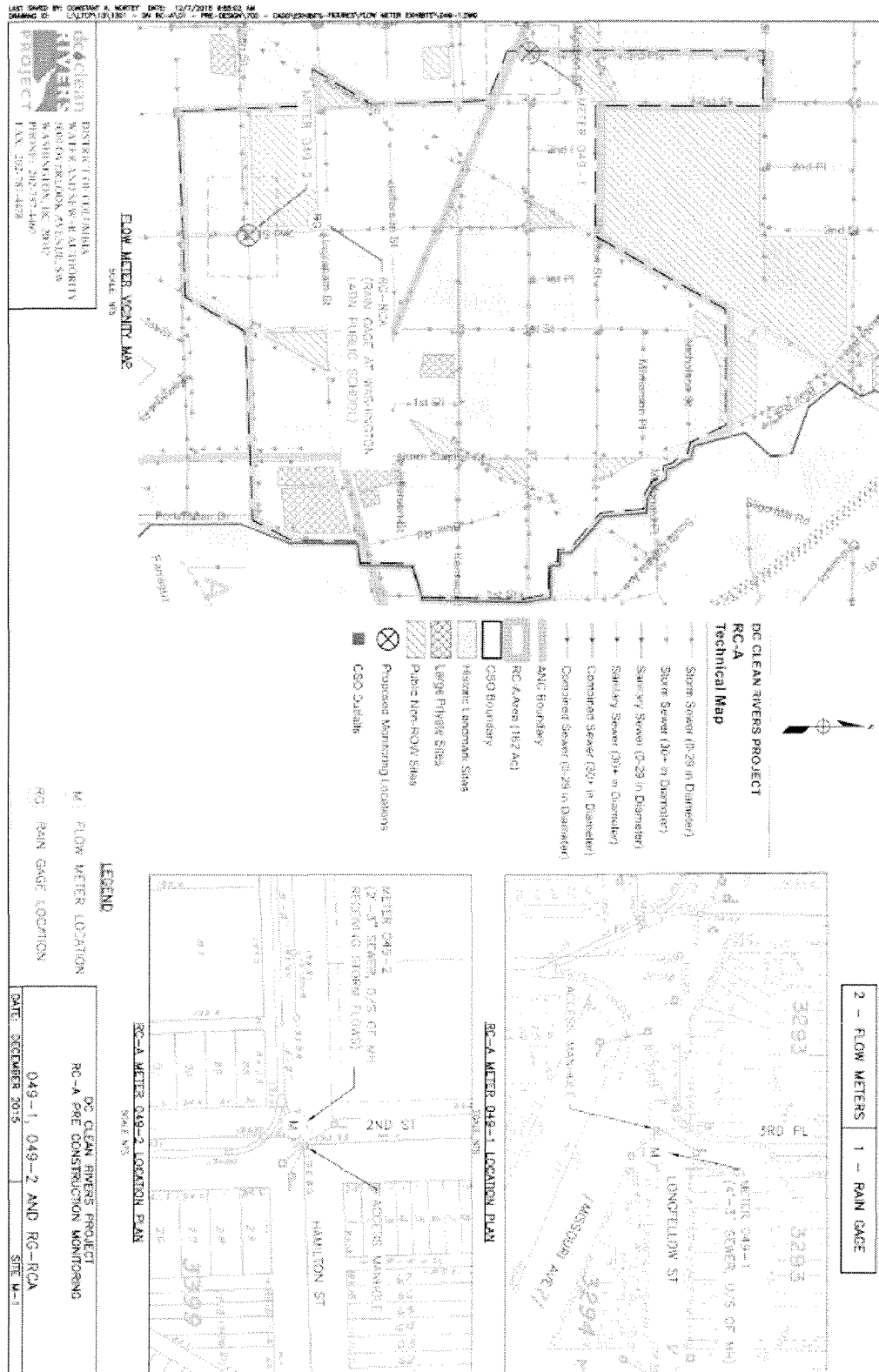


Dimension Structure Detail (pipe profile)



Site Location Plan View

Sketch or plat showing upstream and downstream manholes, connections, and bends.



Site Name/Manhole # 049-3

Primary: ☒ Alternate: ☐

Investigation Date: 1/6/16

Time: 12:20

Crew Members: CL/MH

Installation Date: 1/20/16

Time: 10:15

Crew Members: CL/MH

Address/Location: 6 Hamilton St NW (in the crosswalk)

Latitude: N 38° 57' 12.4"

Longitude: W 77° 00' 33.5"

Weather Conditions: Wet

Dry**Hydraulic Conditions****Influent Flow:**Velocity 0.40 ft/secDepth 1.25 in**Turbulence Amplitude:**☐ Less than 0.25"☒ 0.25" to 0.75"☐ 0.75" to 1.5"☐ 1.5" to 3"☐ Greater than 3"**Sewer Line Characteristics:**

	Influent 1	Influent 2	Influent 3	Effluent
Height	15"	12"	15"	15"
Width	15"	12"	15"	15"
Material	Clay	Concrete	Concrete	Concrete
Shape	Round	Round	Round	Round

Sediment Present: US

☒ Yes Hard packed: _____ in. deep
☐ No Soft: 0.25 in. deep

Surcharge / Backwater Influence:

- ☐ No evidence visible
☐ Remains in pipe
☒ 3 ft from rim
☐ Reaches Rim (potential meter damage)
☐ Evidence unclear: _____ ft from rim

Gas Investigation:☐ Good 20.9 (condition)**Site Conditions****Site Access:** *in crosswalk at traffic light, use cones*☐ Good (no problems accessing site)☒ Fair (minor traffic control, truck accessible off-road site, can safely carry equipment to site)☐ Poor (remote areas, steel embankments, No safe place to park, elevated MH >3 ft)☐ Traffic Control only (Requires extra traffic control)☐ Unusable (Document in Comments section)**Manhole Information:**Elevated Manhole: ☐ Yes ☒ No

Height above ground _____

Manhole depth 11' 9"

Structural Integrity of Manhole:

☐ Good ☒ Fair ☐ Poor**Pipe Bends:** *None within camera view*☐ Influent ☐ Effluent ☐ Manhole

Approx Distance to bend: _____ ft

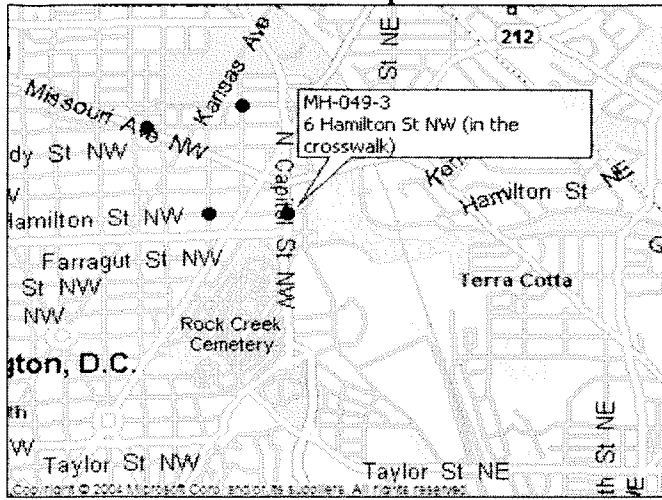
Pipe Size/Geometry/Material Change:☐ Influent ☐ Effluent ☐ ManholeApprox Distance to change: _____ ft
(detail in comments)**Crew Member:** Can you maintain this site?☒ Yes ☐ No ☐ Maybe**Sensor Configuration:**

(Please include Serial Numbers when possible)

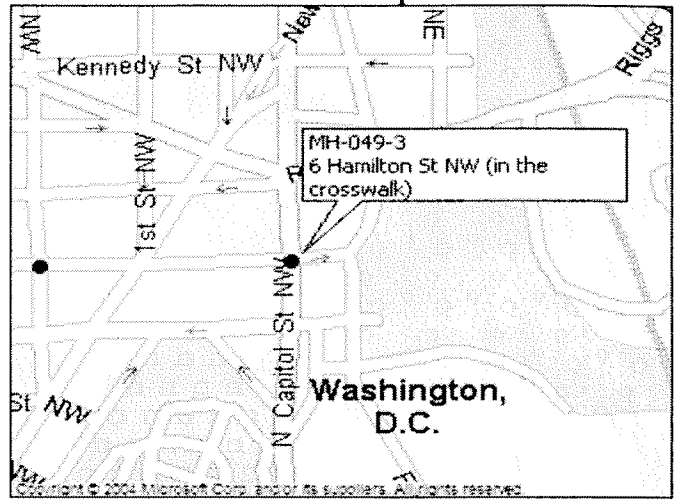
Level	Primary: Isco A/V
	Redundant:
Velocity	Primary: Isco A/V
	Redundant:
Meter Logger	Telog

Comments:

Area Map



Detail Map



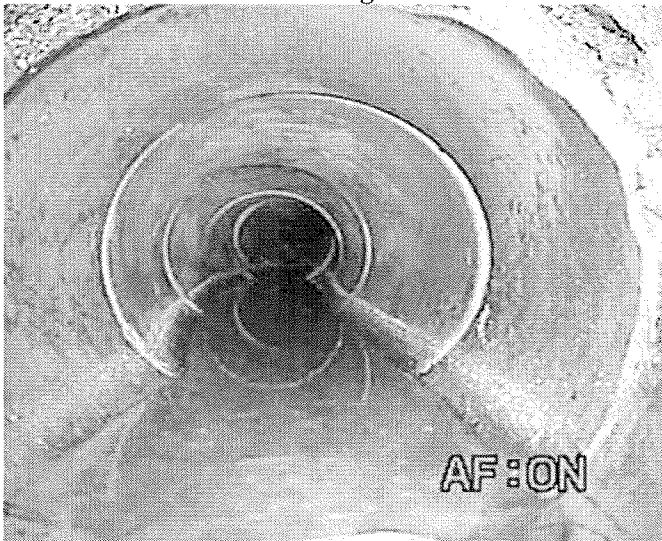
View from top of MH



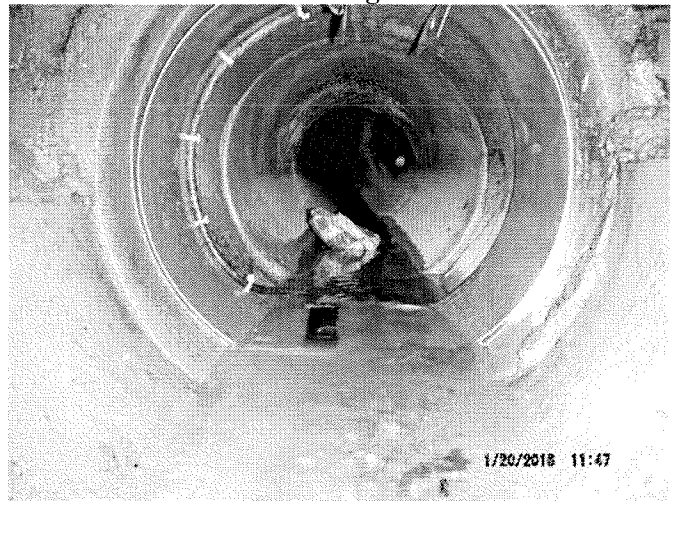
Site Overview



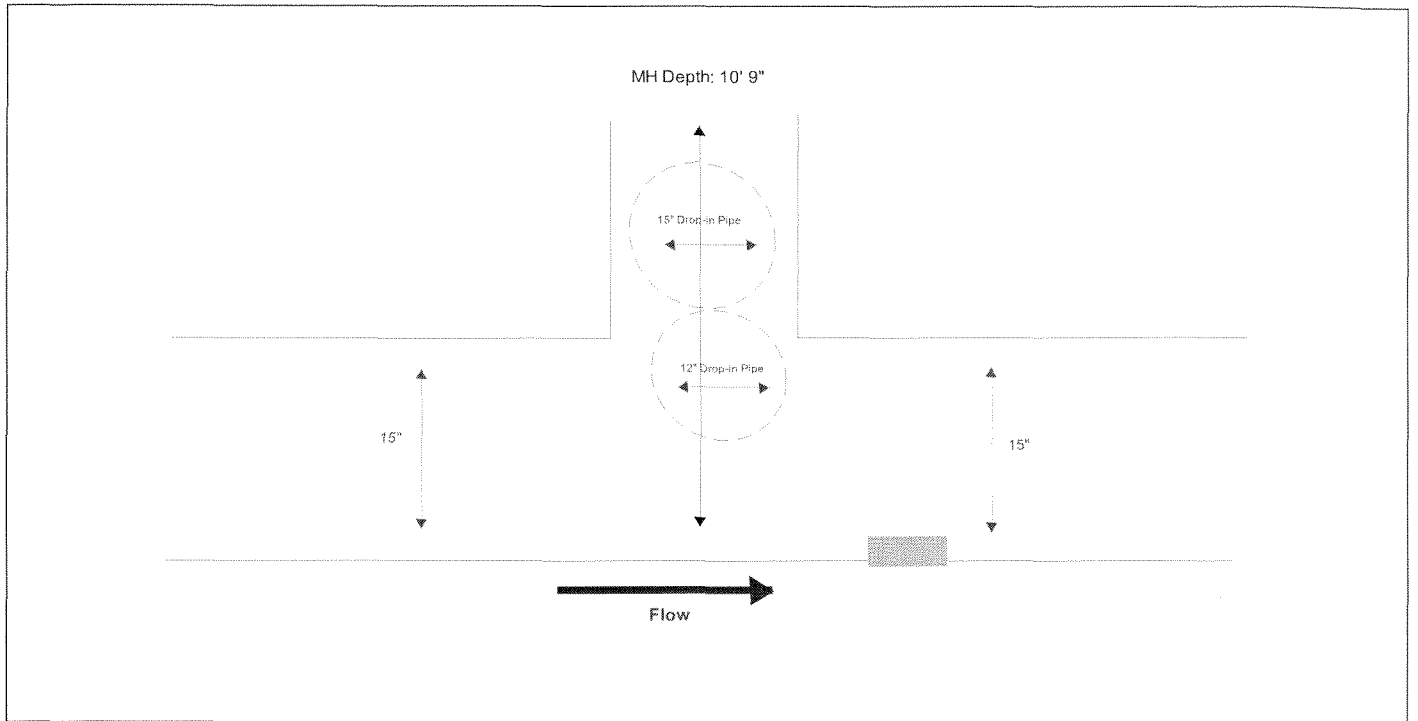
View of flow through influent line



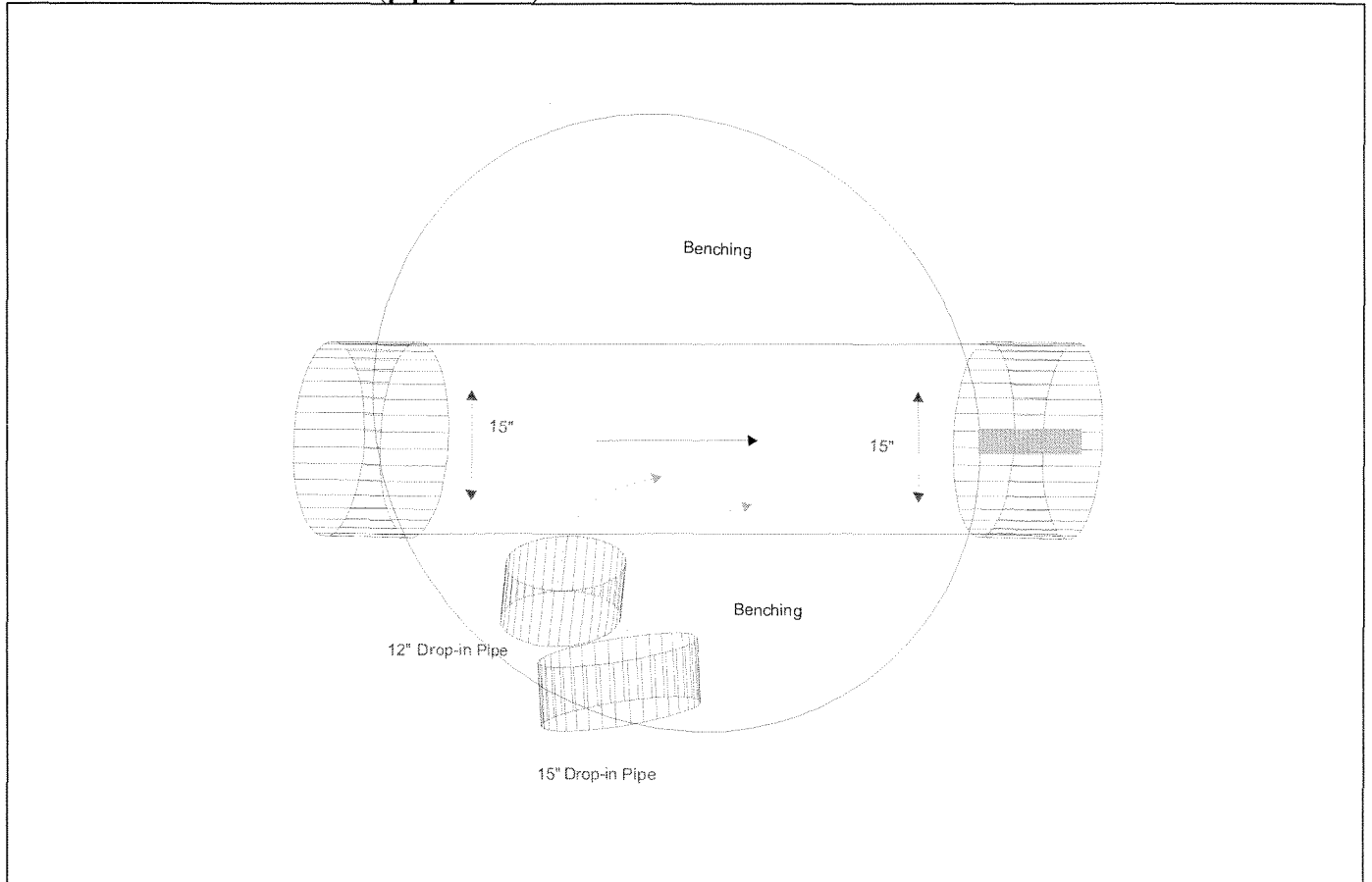
View of flow through effluent line



Dimensional Structure Profile View (profile sketch showing location of sensors)



Dimension Structure Detail (pipe profile)



Site Location Plan View

Sketch or plat showing upstream and downstream manholes, connections, and bends.



Site Name/Manhole # 049-4

Primary: ☒ Alternate: ☐

Investigation Date: 1/6/16

Time: 2:30

Crew Members: CL/MH

Installation Date: 1/20/16

Time: 12:10

Crew Members: CL/MH

Address/Location: In the intersection of 1st Street NW and Madison Street NW

Latitude: N 38° 57' 31.6"

Longitude: W 77° 00' 41.7"

Weather Conditions: Wet

Dry



Hydraulic Conditions

Influent Flow:

Velocity 2.25 ft/sec

Depth 0.25 in

Turbulence Amplitude:

☐ Less than 0.25"

☒ 0.25" to 0.75"

☐ 0.75" to 1.5"

☐ 1.5" to 3"

☐ Greater than 3"

Sewer Line Characteristics:

	Influent 1	Influent 2	Effluent
Height	10"		21"
Width	10"		21"
Material	Clay		Clay
Shape	Round		Round

Sediment Present:

☐ Yes Hard packed: _____ in. deep

☒ No Soft: _____ in. deep

Surcharge / Backwater Influence:

☐ No evidence visible

☐ Remains in pipe

☒ 5 ft from rim

☐ Reaches Rim (potential meter damage)

☐ Evidence unclear: _____ ft from rim

Gas Investigation:

☐ Good 20.9 (condition)

Site Conditions

Site Access: *middle of intersection*

☐ Good (no problems accessing site)

☒ Fair (minor traffic control, truck accessible off-road site, can safely carry equipment to site)

☐ Poor (remote areas, steel embankments, No safe place to park, elevated MH >3 ft)

☐ Traffic Control only (Requires extra traffic control)

☐ Unusable (Document in Comments section)

Manhole Information:

Elevated Manhole: ☐ Yes ☒ No

Height above ground _____

Manhole depth 10' 10"

Structural Integrity of Manhole:

☐ Good ☒ Fair ☐ Poor

Pipe Bends: *None within camera view*

☐ Influent ☐ Effluent ☐ Manhole

Approx Distance to bend: _____ ft

Pipe Size/Geometry/Material Change:

☒ Influent ☐ Effluent ☐ Manhole

Approx Distance to change: 2'

(detail in comments)

Crew Member: Can you maintain this site?

☒ Yes ☐ No ☐ Maybe

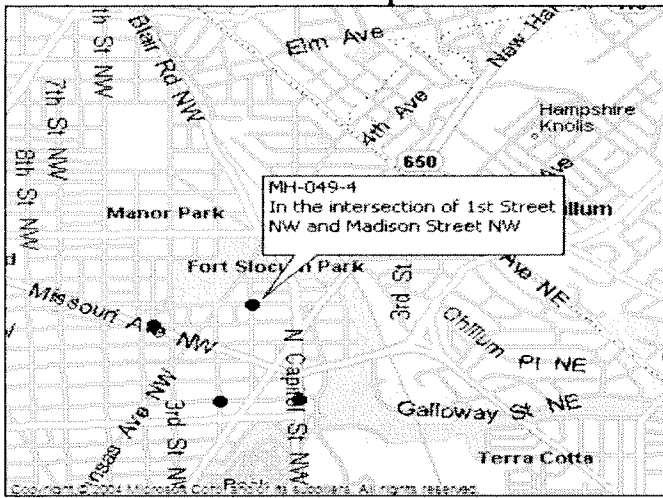
Sensor Configuration:

(Please include Serial Numbers when possible)

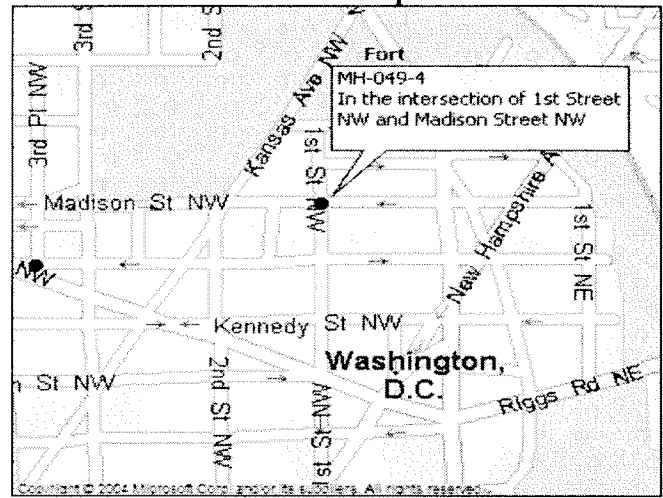
Level	Primary: Flowav
	Redundant:
Velocity	Primary: Flowav
	Redundant:
Meter Logger	Telog

Comments:

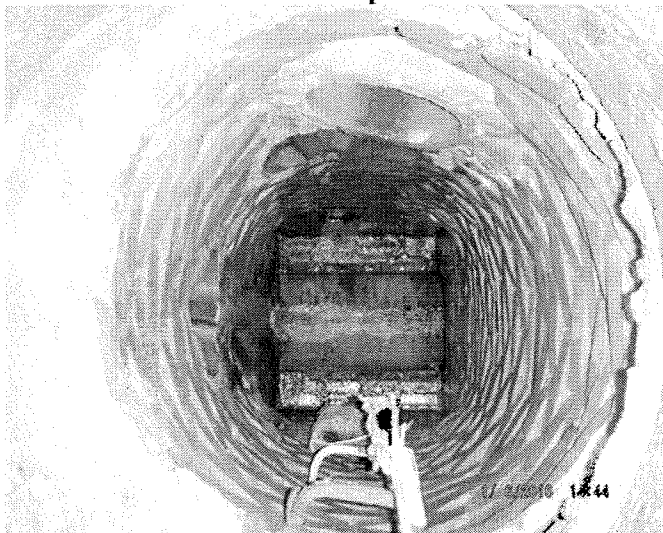
Area Map



Detail Map



View from top of MH



Site Overview



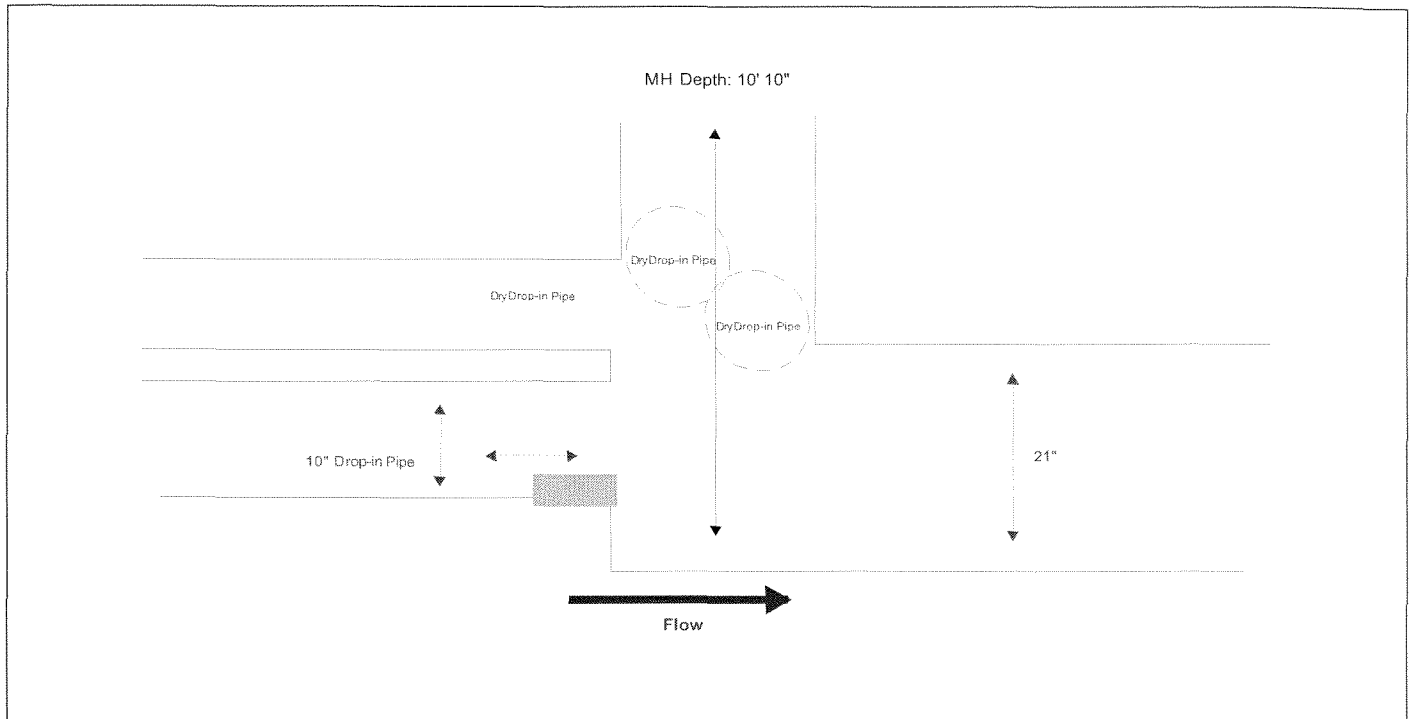
View of flow through influent line



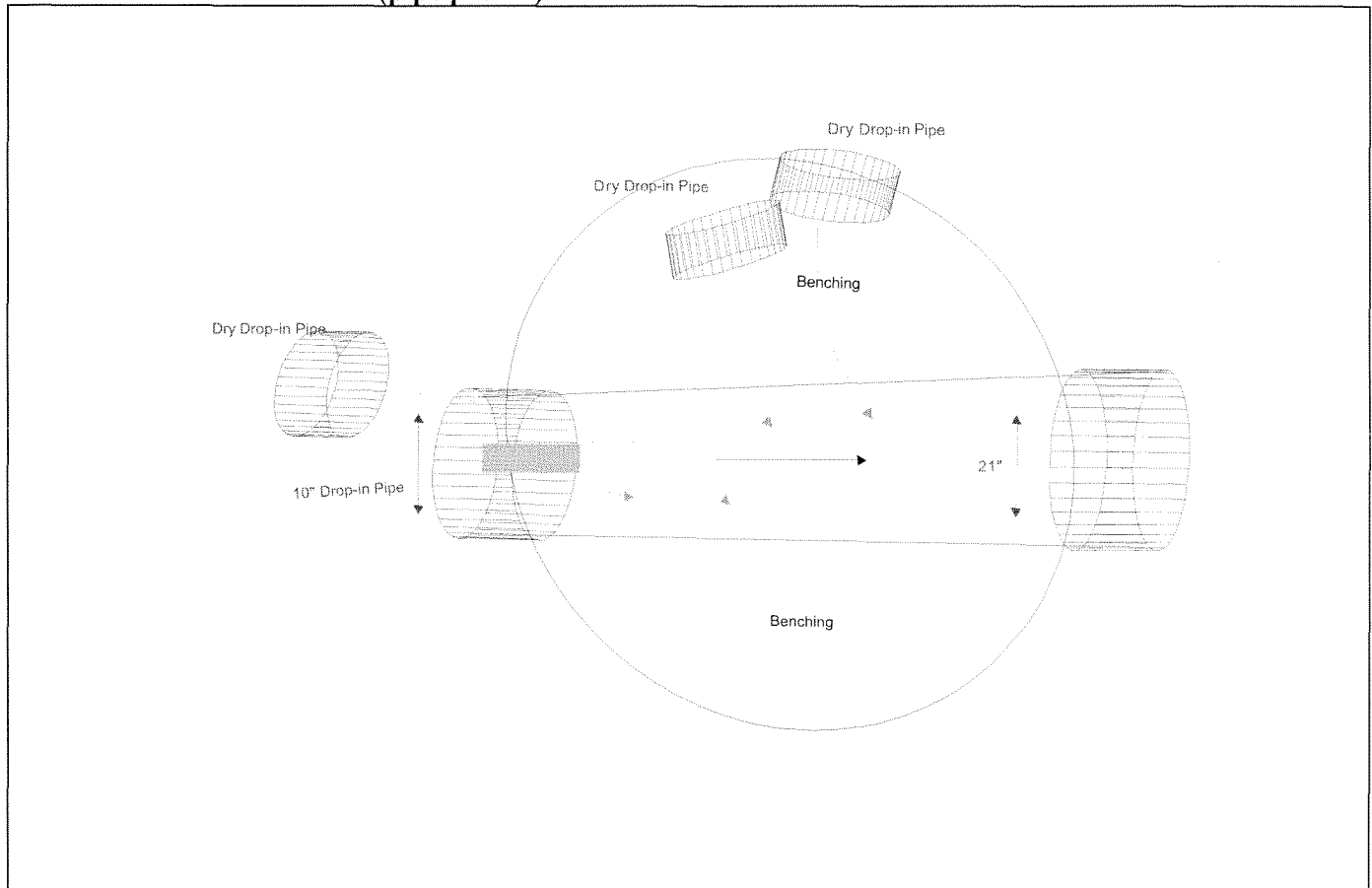
View of flow through effluent line



Dimensional Structure Profile View (profile sketch showing location of sensors)

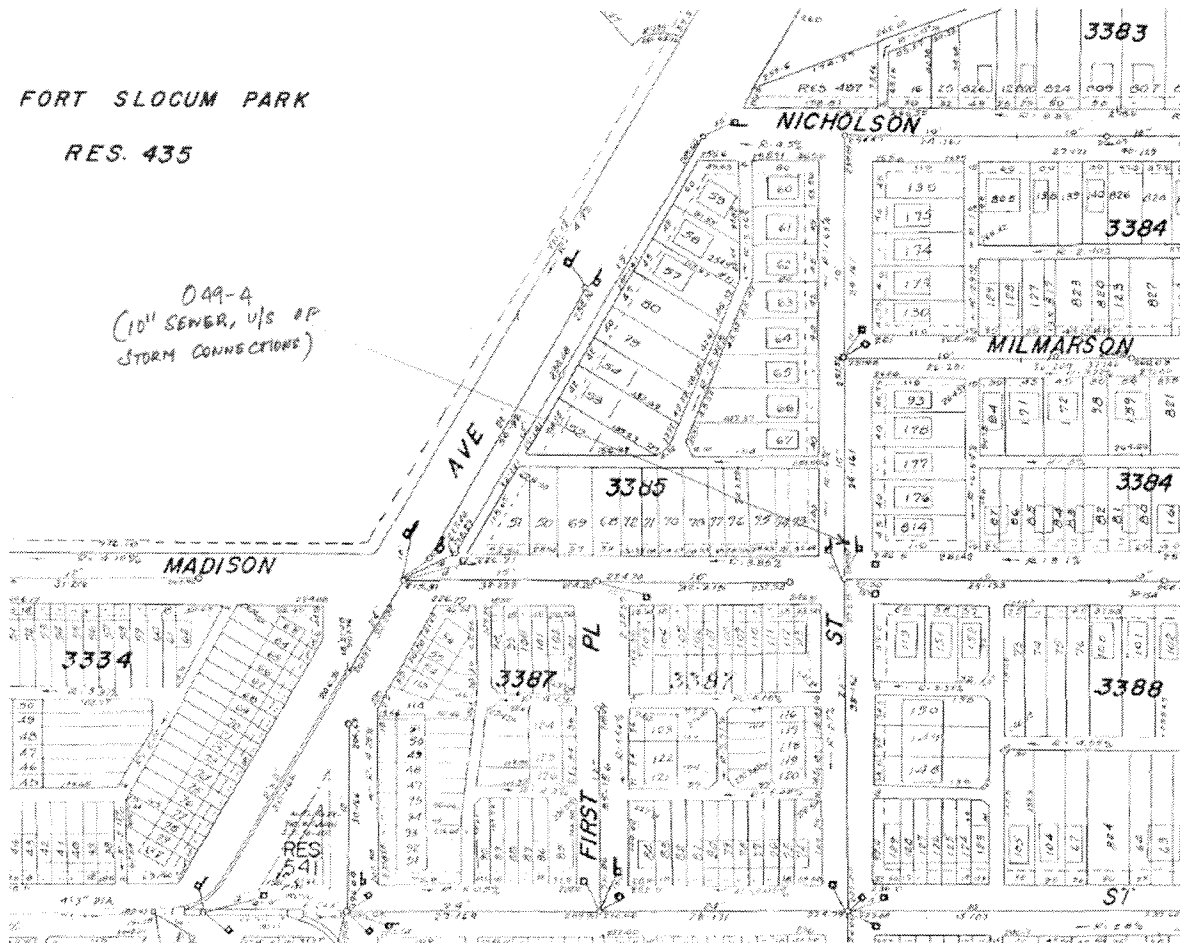


Dimension Structure Detail (pipe profile)



Site Location Plan View

Sketch or plat showing upstream and downstream manholes, connections, and bends.



Appendix B Groundwater Well Installation

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<div style="display: flex; align-items: center;"> <div style="margin-right: 20px;"> </div> <div> <h2 style="margin: 0;">Log of Boring RCAGI-01</h2> </div> </div>																																																																					
<p>PROJECT: DC Clean Rivers Project- Green Infrastructure</p> <p>PROJECT LOCATION: WASHINGTON DC COORD. SYS./DATUM: MD NAD 83/NAVD88</p> <p>PROJECT NUMBER: DCFA # 421-WSA COORDINATES: N 471305.7 E 1307486.6</p>																																																																					
<p>DATE STARTED: 11/20/2015</p> <p>DATE COMPLETED: 11/25/2015</p> <p>LOGGED BY: A. Shah/ M. Lewis</p> <p>CHECKED BY: K. Bell</p> <p>DRILLING CONTRACTOR: SALUT</p> <p>DRILL RIG: Vac Truck</p> <p>DRILLER: Daniel Pilachowski</p>	<p>DRILL METHOD: Air Knife</p> <p>HAMMER TYPE/WEIGHT: NA/NA</p> <p>CASING TYPE: NA</p> <p>CASING SIZE: NA</p> <p>BIT TYPE/SIZE: NA/ NA</p> <p>BOREHOLE DEPTH: 7.5 FT</p> <p>SURFACE ELEVATION: 199.50 FT</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="5">Groundwater Observations</th> </tr> <tr> <th></th> <th>Date</th> <th>Time</th> <th>Depth (ft)</th> <th>Casing Depth (ft)</th> </tr> </thead> <tbody> <tr> <td>Encountered</td> <td>11-20-2015</td> <td>-</td> <td>DRY</td> <td>-</td> </tr> <tr> <td>24-hour</td> <td>11-23-2015</td> <td>-</td> <td>DRY</td> <td>-</td> </tr> </tbody> </table>	Groundwater Observations						Date	Time	Depth (ft)	Casing Depth (ft)	Encountered	11-20-2015	-	DRY	-	24-hour	11-23-2015	-	DRY	-																																															
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<div style="display: flex; flex-direction: column; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">DEPTH (FT)</div> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">ELEV. (FT)</div> </div>	<div style="display: flex; flex-direction: column; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">DESCRIPTION</div> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">USCS</div> <div style="writing-mode: vertical-rl; transform: rotate(180deg);">GRAPHIC LOG</div> </div>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="3">SAMPLES</th> <th rowspan="2">WELL</th> <th rowspan="2">MOISTURE CONTENT</th> <th rowspan="2">Hydrologic Soil Group</th> <th rowspan="2">Infiltration Rate (inches/hr)</th> <th rowspan="2">REMARKS AND TESTS</th> </tr> <tr> <th>NUMBER</th> <th>TYPE</th> <th>DCP BLOWS (PER 1.75")</th> </tr> </thead> <tbody> <tr> <td colspan="3" style="height: 20px;">Asphalt (0.0' - 0.2')</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td colspan="3" style="height: 20px;">Concrete (0.2' - 0.75')</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td colspan="3" style="height: 20px;">Moist, gray with streaks of brown, fine to coarse, SILTY SAND, estimated 15 - 25% fines</td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td style="text-align: center;">197.5</td> <td style="text-align: center;">2.5</td> <td style="text-align: center;">Moist, gray with streaks of brown, low plasticity, SANDY LEAN CLAY, estimated 30 - 45% fine to coarse sand, contains streaks of black</td> <td style="text-align: center;">B-1</td> <td style="text-align: center;">5-5-2</td> <td style="text-align: center;">8" (100%)</td> <td style="text-align: center;">D</td> <td></td> </tr> <tr> <td style="text-align: center;">195.0</td> <td style="text-align: center;">5.0</td> <td style="text-align: center;">Moist, gray with streaks of brown, fine to coarse, CLAYEY SAND WITH GRAVEL, estimated 30 - 45% fines, estimated 15 - 25% fine gravel</td> <td style="text-align: center;">B-2</td> <td style="text-align: center;">3-4-8</td> <td style="text-align: center;">8" (100%)</td> <td></td> <td></td> </tr> <tr> <td style="text-align: center;">192.5</td> <td style="text-align: center;">7.5</td> <td style="text-align: center;">Moist, gray with streaks of brown, fine to coarse, CLAYEY SAND WITH GRAVEL, estimated 30 - 45% fines, estimated 15 - 25% fine gravel</td> <td style="text-align: center;">B-3</td> <td style="text-align: center;">8" (100%)</td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td style="text-align: center;">B-4</td> <td style="text-align: center;">6" (100%)</td> <td style="text-align: center;">A</td> <td style="text-align: center;">1.2</td> <td style="text-align: center;">7.0': Sample B-4 taken after infiltration test.</td> </tr> </tbody> </table>	SAMPLES			WELL	MOISTURE CONTENT	Hydrologic Soil Group	Infiltration Rate (inches/hr)	REMARKS AND TESTS	NUMBER	TYPE	DCP BLOWS (PER 1.75")	Asphalt (0.0' - 0.2')								Concrete (0.2' - 0.75')								Moist, gray with streaks of brown, fine to coarse, SILTY SAND, estimated 15 - 25% fines								197.5	2.5	Moist, gray with streaks of brown, low plasticity, SANDY LEAN CLAY, estimated 30 - 45% fine to coarse sand, contains streaks of black	B-1	5-5-2	8" (100%)	D		195.0	5.0	Moist, gray with streaks of brown, fine to coarse, CLAYEY SAND WITH GRAVEL, estimated 30 - 45% fines, estimated 15 - 25% fine gravel	B-2	3-4-8	8" (100%)			192.5	7.5	Moist, gray with streaks of brown, fine to coarse, CLAYEY SAND WITH GRAVEL, estimated 30 - 45% fines, estimated 15 - 25% fine gravel	B-3	8" (100%)							B-4	6" (100%)	A	1.2	7.0': Sample B-4 taken after infiltration test.
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<p>BORING COMPLETED AT 7.5 FT ON 11/25/2015 AT 1100 HOURS. Upon completion, set 5" PVC pipe for infiltration test. Infiltration test performed on 11/24/2015. Installed 2" PVC monitoring well with 0.020" well screen placed from 2' to 7' on 11/25/2015.</p> <p><u>Note 1:</u> Soil Samples were field screened for soil vapors using a MultiRAE 4-gas meter at 2', 4' and 6'. Screening for VOC's, LEL, and H2S are "Not Detected", and O2 was 20.9% unless otherwise noted.</p> <p><u>Note 2:</u> Hydrologic soil group based on USDA classification at the depth of the group letter. Refer to Tables 2 and 4 of the GDR.</p>																																																																					
<div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> <p>DC Clean Rivers Project 5000 Overlook Avenue, SW, Washington DC, 20032 Phone: 202.787.2251 Fax: 202.787.2297</p> </div> <div style="width: 40%;"> <p>B = Bulk Sample S = Split Spoon Sample D = Denison Sample</p> <p>G = Geoprobe T = Shelby Tube Sample RC = Rock Core</p> <p>P = Pitcher Sample SC = Sonic Core</p> </div> <div style="width: 30%; text-align: right;"> <p>SHEET 1 of 1</p> </div> </div>																																																																					

SSC BORINGS LTCP_FINAL_DATABASE GI RC.GPJ LTCP_FINAL_DATABASE.GPJ 6/7/16 REV.4

EXHIBIT E

Form of Opinion of DC Water's General Counsel

September 29, 2016

District of Columbia Water and Sewer Authority
5000 Overlook Avenue, S.W.
Washington, D.C. 20032

\$25,000,000
DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY
Public Utility Subordinate Lien Multimodal Revenue Bonds
Series 2016B
(Environmental Impact Bonds)

Ladies and Gentlemen:

I am the General Counsel to the District of Columbia Water and Sewer Authority (the "Authority") and, in connection with the issuance by the Authority of its Public Utility Subordinate Lien Multimodal Revenue Bonds, Series 2016B (Environmental Impact Bonds), in the original principal amount of \$25,000,000 (the "Series 2016B Bonds"), I have reviewed an executed copy of the Private Placement Agreement, dated September 28, 2016, between the Authority, Goldman, Sachs & Co. and Calvert Social Investment Foundation, Inc., with respect to the Series 2016B Bonds (the "Private Placement Agreement"). Capitalized terms used and not defined herein shall have the respective meanings given to such terms in the Private Placement Agreement.

I have also examined an act of the Council of the District of Columbia entitled the "Water and Sewer Authority Establishment and Department of Public Works Reorganization Act of 1996," codified, as amended, at District of Columbia Official Code Ann. Sections 34-2201.01 *et seq.*, and the acts amendatory thereof and supplemental thereto (the "Act"), and an act of the United States Congress entitled the "District of Columbia Water and Sewer Authority Act of 1996" (Public Law 104-184), as amended (the "Federal Act"), certified copies of proceedings of the Authority authorizing the issuance of the Series 2016B Bonds, including the Resolution and such other proceedings as I have considered necessary or advisable to render the following opinions.

In rendering the following opinions, I have relied on representations of the Authority as to matters of fact without independent investigation or verification and, as to matters of law, the representations of Bond Counsel without independent research or verification and have assumed the genuineness of all signatures, the authenticity of all documents tendered to me as originals and the conformity to original documents of all documents submitted to me as certified or photostatic copies.

Based upon review of the materials described above and subject to the recitals and qualifications herein contained, to the best of my knowledge, information and belief, it is my opinion that:

1. The Authority is a body corporate duly created, organized and validly existing as an independent authority of the District under the Act and under the Federal Act (the Act and the Federal Act being sometimes hereinafter referred to as, the “Acts”). The Authority has the full legal right, power and authority to (i) adopt the Resolution, (ii) issue the Series 2016B Bonds, (iii) execute, deliver and perform its obligations under the Bond Documents, and (iv) perform its obligations under the System Agreements.

2. The Federal Act was duly enacted by Congress and the Act was duly enacted by the Council of the District of Columbia. The Acts remain in full force and effect. The Act transferred all assets and liabilities of the Water and Sewer Utility Administration (“WASUA”) as indicated on the balance sheet prepared by WASUA, effective April 17, 1996, on an interim basis for the exclusive use and possession of the Authority for so long as any revenue bonds of the Authority, including the Series 2016B Bonds, remain outstanding.

3. The Resolution was adopted by the Authority and has not been amended since the date of the adoption thereof and remains in full force and effect as of the date hereof.

4. (i) The adoption of the Resolution, the issuance of the Series 2016B Bonds, the execution and delivery of the Bond Documents and the performance of the Authority’s obligations thereunder, and (ii) the performance of the Authority’s obligations under the System Agreements, under the circumstances contemplated thereby, do not and will not in any material respect conflict with or constitute on the part of the Authority, a breach of or default under any agreement or other instrument to which the Authority is a party, or any existing law, administrative regulation, court order, settlement order or consent decree to which the Authority is subject.

5. There is no action, suit, proceeding, inquiry or investigation, at law or in equity, before or by any court, government agency, public board or body, pending or, to the best of my knowledge, threatened against the Authority (i) seeking to prohibit, restrain or enjoin the issuance, sale or delivery of the Series 2016B Bonds, or the collection of the revenues pledged to the payment of the principal of and interest on the Series 2016B Bonds, (ii) in any way contesting or affecting any authority for the issuance of the Series 2016B Bonds or the validity, enforceability, due authorization, execution or delivery of the Series 2016B Bonds, including the Private Placement Agreement or the other Bond Documents, or the validity or enforceability of the System Agreements, (iii) questioning the tax-exempt status of the Series 2016B Bonds under the laws of the District or the United States, (iv) in any way contesting the corporate existence or powers of the Authority or the titles of the officers of the Authority to their respective offices, or (v) which may result in any material adverse change in the business or the financial condition or the financial prospects of the Authority.

6. Pursuant to the Acts, the Authority has the full legal right, power and authority to operate the System and to collect and pledge the Revenues therefrom in accordance with the Indenture.

7. The Authority has obtained the consents, approvals, authorizations or other orders required for the consummation of the transactions contemplated by the Private Placement Agreement, including the issuance of the Series 2016B Bonds.

This opinion and all documents which relate to this opinion are to be construed in accordance with the laws of the District and the United States of America. This opinion is rendered solely for the use of the Authority and may not be relied on by any other person.

Very truly yours,

General Counsel

Exhibit F

Form of Opinion of the Purchasers' Legal Counsel

September 29, 2016

\$25,000,000

**DISTRICT OF COLUMBIA WATER AND SEWER AUTHORITY
Public Utility Subordinate Lien Multimodal Revenue Bonds, Series 2016B
(Environmental Impact Bonds)**

District of Columbia Water and Sewer Authority
5000 Overlook Avenue, S.W.
Washington, D.C. 20032

Ladies and Gentlemen:

We have acted as counsel to GSUIG Real Estate Member LLC and Calvert Social Investment Foundation, Inc., each a purchaser (collectively, the "Purchasers") in connection with their purchase from the District of Columbia Water and Sewer Authority (the "Authority") of its Public Utility Subordinate Lien Multimodal Revenue Bonds, Series 2016B (Environmental Impact Bonds), in the original principal amount of \$25,000,000 (the "Bonds"), pursuant to the Private Purchase Agreement, dated September 28, 2016 (the "Purchase Agreement"), between you and the Purchasers. The Bonds are to be issued pursuant to the Master Indenture of Trust, dated as of April 1, 1998 (the "Master Indenture"), between the Issuer and Wells Fargo Bank, N.A., as trustee (the "Trustee"), as amended and supplemented, including by the Twenty-First Supplemental Indenture of Trust, dated as of the Closing Date (the "Twenty-First Supplemental Indenture," and together with the Master Indenture as previously amended and supplemented, the "Indenture"), between the Issuer and the Trustee. The proceeds of the Bonds will be used to (i) pay a portion of the costs of the Project, and (ii) pay costs of issuing the Bonds. Capitalized terms not otherwise defined herein shall have the meanings ascribed thereto in the Purchase Agreement.

In that connection, we have reviewed the Indenture, the Purchase Agreement, certificates of the Authority, the Trustee and others, the opinions referred to in paragraph 6(f) of the Purchase Agreement, and such records and documents, and we have made such investigations of law, as we have deemed appropriate as a basis for the opinions and conclusions hereinafter expressed.

The opinions expressed herein are based on an analysis of existing laws, regulations, rulings and court decisions and cover certain matters not directly addressed by such authorities. Such opinions may be affected by actions taken or omitted or events occurring after the date hereof. We have not undertaken to determine, or to inform any person, whether any such actions

are taken or omitted or events do occur or any other matters come to our attention after the date hereof. Accordingly, this opinion speaks only as of its date and is not intended to, and may not, be relied upon or otherwise used in connection with any such actions, events or matters. Our engagement with respect to the Bonds has concluded with their issuance, and we disclaim any obligation to update this letter. We have assumed the genuineness of all documents and signatures presented to us (whether as originals or as copies) and the due and legal execution and delivery thereof by, and validity against, any parties other than the Purchasers. We have assumed, without undertaking to verify, the accuracy of the factual matters represented, warranted or certified in the documents, and of the legal conclusions contained in the opinions, referred to in the second paragraph hereof. We call attention to the fact that the rights and obligations under the Purchase Agreement and their enforceability may be subject to bankruptcy, insolvency, receivership, reorganization, arrangement, fraudulent conveyance, moratorium and other laws relating to or affecting creditors' rights, to the application of equitable principles, and to the exercise of judicial discretion in appropriate cases. We express no opinion with respect to any indemnification, contribution, liquidated damages, penalty (including any remedy deemed to constitute a penalty), right of set-off, arbitration, choice of law, choice of forum, choice of venue, non-exclusivity of remedies, waiver or severability provisions contained in the foregoing documents, nor do we express any opinion with respect to the state or quality of title to or interest in any of the real or personal property described in or as subject to the lien of the Indenture or the accuracy or sufficiency of the description contained therein of, or the remedies available to enforce liens on, any such property. Our services did not include financial or any other non-legal advice.

Based on and subject to the foregoing, and in reliance thereon, as of the date hereof, we are of the following opinion:

1. The Purchase Agreement, when duly executed and delivered by the Purchasers, will constitute the legal, valid and binding obligation of Purchasers.

We are furnishing this letter to you pursuant to paragraph 6(g) of the Purchase Agreement solely for your benefit as the Authority. We disclaim any obligation to update this letter. This letter is not to be used, circulated, quoted or otherwise referred to or relied upon for any other purpose or by any other person. This letter is not intended to, and may not, be relied upon by owners of Bonds or by any other party to whom it is not specifically addressed.

Very truly yours,

ORRICK, HERRINGTON & SUTCLIFFE LLP