APPENDIX A

WATER QUALITY VOLUME CALCULATIONS

WATER QUALITY PEAK FLOW CALCULATIONS

Appendix A

• Application of the Numerical Criteria in Part 4.D of the Los Angeles County MS4 Permit

A-1 Water Quality Volume for Bioretention Cells and Underground Infiltration Basins

The Los Angeles County MS4 Permit, (Regional Board Order No. 01-182, NPDES Permit No CAS004001) has four numerical design criteria for volume based BMPs:

1. The 85th percentile, 24-hr runoff event determined as maximized captured storm water volume for the area, from the formula recommended in Urban Runoff Quality Management (URQM), WEF Manual of Practice No. 23, ASCE Manual of Practice No. 87, 1998. or

2. The volume of annual runoff based on unit basin storage water quality volume, to achieve 80 percent or more volume treatment by the method recommended in California Storm Water BMP Handbook, Industrial-Commercial,1993. or

3. The volume of runoff produced from a 0.75 inch storm event, prior to its discharge to a storm water conveyance system. or:

4. The volume of runoff produced from a historical-record based reference 24-hr rainfall criterion for treatment (0.75 inch average for the Los Angeles County area) that achieves approximately the same reduction in pollutant loads achieved by the 85th percentile 24-hr runoff event.

Through meetings with staff of the California Regional Water Quality Control Board, Los Angeles Region, Adams Engineering have determined that criteria No. 3 can be used to size the water quality volume (Q_{WV}) based BMPs for Sam's Club, El Monte Project [i.e., nine bioretention cells (biocells) and two underground infiltration basins (UIBs)].

The basic equation for Q_{WV} determination is as follows:

$$Q_{WV} = 3630 \cdot A \cdot 0.75 \cdot C = 2722.5 A \cdot C \qquad (1)$$

where Q_{WV} is the water quality volume of the BMP in ft^3, A is the area draining to the BMP in acres, and C is the runoff coefficient determined with the CASQA equation (see equation (2)).

$$C_d = f_P C_u + 0.90(1 - f_P) \qquad (2)$$

In equation (2), C_u is a function of the intensity and the soil type. For the type of soil existing in situ, the value of C_u is independent of the intensity (and equal to 0.1) if rainfall intensity (I) < 1.04 in/hr.

A 0.75"-24hr storm event may never have intensity larger than half of 1.04 in/hr according to the rainfall distribution in Table B-1 of the Draft LAC Stormwater BMP Manual.

Therefore, C_u can be assumed constant and equal to 0.1 and only the pervious fraction and the area will determine the Q_{WV} value.

The following table provides the Q_{WV} volume as determined with Criteria 3.

Water Quality Volume

BMPs	Sub-Area	A, acres	Fp (frac perv)	$C^{(6)}$	P, inch	Q_{WV} (ft^3)
Biocell 1	1A	1.34	0.129	0.797	0.75	**2906**
Biocell 2	5	1.64	0.063	0.849	0.75	**3791**
Biocell 3	6	0.98	0.073	0.842	0.75	**2248**
Biocell 4	7	0.63	0.192	0.746	0.75	**1290**
Biocell 5	9	1.89	0.164	0.769	0.75	**3965**
Biocell 6	10	0.52	0.151	0.779	0.75	**1097**
Biocell 7	11	1.39	0.107	0.814	0.75	**3085**
Biocell 8	12	0.77	0.112	0.810	0.75	**1698**
Biocell 9	13	0.41	0.222	0.723	0.75	**813**
UIB-1 (1)	1B to 6, 8	6.03	0.036	0.871	0.75	**14311**
UIB-2 (2)	11	1.39	0.107	0.814	0.75	**3085**

(1): The Q_{WV} obtained assumes that no upstream BMP is treating a portion of the runoff produced. Since Biocell 2 and 3 will reduce part of the runoff volume going to UIB-1 and Biocell-7 will reduce the runoff volume going to UIB-2, the reduction of Q_{WV} has to be taken into account when the design of the Biocells and UIB is performed.

It can be seen in the previous Water Quality Volume Tabulationthat some areas (i.e., 5, 6 and 11) are mentioned in two different BMPs. The reason is that Biocells 3 and 4 (upstream volume BMPs for Areas 6 and 7) and Biocell 7 (upstream volume BMP for Area 11) are not large enough to treat the required Q_{WV}.

Therefore, the excess runoff will drain to UIB-1 or UIB-2, and those areas become part of the drainage area of the UIB-1 and UIB-2. However, during the design of the underground infiltration basins, the runoff already treated by the aforementioned bioretention cells will be subtracted from the Q_{WV} volume needed for the underground infiltration basins as explained in the previous table.

A-2 Design Criteria for Bio-Retention Cells

A-2.1 Design and Sizing Guidelines

The design and sizing guidelines were based on the Draft LAC Stormwater BMP Manual, the CASQA Handbook, and the Bioretention Manual of Prince George County, Maryland, December 2002 (Prince George County Manual).

Additionally, continuity and Darcy's equations were used to determine the treated volume by BMP for each site-specific condition.

A-2.2 Bio-Retention Cell Layers

Following CASQA Handbook, the biocell layers are designed from bottom to top as follows:

- At least eight inches of a gravel layer, ½" – 1 ½" in diameter, rounded. The bottom of this layer is not horizontal in those biocells where french drains are provided, due to the slope of the perforated pipes (from 0.25 percent to 0.5 percent). Due to the slope and length of the french drains, the gravel layer may increase to more than 10 inches because the top of the gravel is horizontal, but for calculation purposes the gravel layer is assumed equal to eight inches (minimum depth at the upstream end of the perforated pipes).

- A six-inch sand layer above the gravel layer. The top gravel layer is horizontal, and the sand layer is also horizontal.

- An amended soil mixture layer, with a depth that depends on the location of the biocell. The minimum depth is 31 inches and the maximum 43 inches.

- A three-inch layer of mulch, (minimum value recommended by the City of El Monte, and in the range of thickness recommended by all references).

- A six-inch ponding-depth volume, where the bottom corresponds to the top of the mulch and the top is equal to the invert elevation of the outlet structure required to discharge large flood events. The slopes from the bottom of the biocell to the adjacent topography will be either 3:1 or 4:1 depending on the space constrains and the required extension to match the existing topography surrounding the biocell (for instance, if the bottom of the biocell is more than 1.5 feet (ft) deeper than the surrounding area, a slope of 4:1 is preferred to avoid a possible tripping hazard).

A-2.3 Soil Mixture Properties

The soil mixture should have an infiltration rate of at least 0.5 in/hr (saturated hydraulic permeability) according to the references above. The permeability values for two soil samples taken at 0 to 5 ft. deep was in the range of 0.0024 in/hr to 0.0076 in/hr [clayed silt (ML) and sandy silt with clay (ML)]. Both soils are unsuitable for soil mixture. However, according to the El Monte Geotechnical Report prepared by Krazan & Associates Inc in January 2006, original soils can be encountered throughout the site [silty sands (SM)] after 5 to 7 ft. deep and a permeability test for this soil type shown in The El Monte Percolation Study by Krazan & Associates Inc, September 2006, gave a permeability value of 0.98 in/hr.

Therefore, it is recommended that this type of soil must be used for the soil mixture, amended with organics (leaf compost), and sand, avoiding the use of top soil unless sand is added also to the mixture to satisfy the following constrains:

- pH range: 5.5 to 6.5 (per all references)

- Organic matter: 1.5 percent to 3 percent (per all references)

- Sand: 45 percent to 60 percent (35 percent to 60 percent by volume based on the Draft LAC Stormwater BMP Manual and 50 to 60 percent based on the Prince George County

Manual). An intermediate value of 45 percent was selected as minimum value.

- Clay: Clay content should be less than 12 percent (per a combination of the references, since the criteria is 10 to 25 percent per CASQA Handbook and Draft LAC Stormwater BMP Manual or less than 5 percent per Prince George County Manual).
- Due to the disagreement in the references, a soil triangle analysis was performed and it was determined that the clay content can not exceed 12 percent in order to have a saturated hydraulic conductivity of 1 in/hr or more with the clay and organic content constrains already specified.

A-2.4 In Situ soils Suitable for Amended Mixture

From an analysis of the soil borings close to or at the location of the biocells, the following soils can be used for the soil-sand-organics mixture:

1. Soils 2 ft deep or deeper in the area of Biocell 1 (SM soils mainly, sandy silts, or silty sands without clays. See borings B-20 and B-21)
2. Soils 4 ft deep in the area of Biocell 2 (see boring B-43)
3. Soils at least 6.5 ft deep in the Biocell 3 location (see boring B-42)
4. Soils 3 or more ft deep in the Biocell 4 location (ML and SM soils, boring B-41)
5. Soils 1 ft deep or deeper in the Biocell 5 location (SM and sands, excellent permeable soils, see boring B-48)
6. Soils at least 1 ft deep in the area of Biocell 6 location (see boring B-47)
7. Soils at least 3 ft deep in the area of Biocell 7 (SM soils, see boring B-37)
8. There are no good soils in the area of Biocell 8 until after 8.5 ft deep (see borings B-39 and B-55)
9. SM soils at least 1 ft deep in the area of Biocell 9 (see boring B-52).

From the analysis of the borings, soils of the type: silty sands (SM), silty sand/sandy silt mixtures (SM/ML), sandy silts without clay (ML), sands with traces of silt/gravel and organics (SP), and sands in general (SP) are preferred.

Soils of the type clayed silts with or without some sand (ML), silty clays (CL) and soils with high clay content must be avoided in the mixture because of their low permeability.

A-2.5 Minimum Depth Criteria

According to the Draft LAC Stormwater BMP Manual, and the CASQA Handbook, soil depth must be at least four feet, but according to the Prince George County Manual, the specified soil mix can be as shallow as 18 inches. Since french-drains will be provided in most of the biocells, and they should drain to the drainage system, the invert elevation of the discharge MS4 limits the soil depth of the biocells.

Therefore, the selected soil depth for the mixture will be as much as possible (from 31 inches minimum at Biocell-5, Biocell-6 and Biocell-8 to 43 inches maximum to Biocell-1, Biocell-2, Biocell-4 and Biocell-7).

A-2.6 Sequence of Calculation

Required variables:

A_B : Area of the bottom of the biocell in ft^2. It is determined based on the available landscape space and the elevations around the biocell, grading the area with a slope 3:1 or 4:1 (depending on the case) to reach the top elevation required.

P : Ponding depth usually is around 6 inches to 8 inches to avoid ponding water for long periods of time. The more permeable the soil is, the highest this value can be. In this case, we conservatively select a value of 0.5 ft.

A_T: Area of the top of the biocell. Once A_B and P are known, the bottom area is offset a distance equal to P·z feet, where P is the ponding depth and z is the slope around the biocell. In our case, the offset distance is 1.5 ft if z=3 and 2 ft, if z=4.

M : Mulch depth in feet. A value of 3 inches is selected, and the mulch is placed up to the invert elevation of the outlet structure.

η_M : Mulch porosity. It is assumed that the porosity of the mulch is similar to that of uniform size gravel. Therefore $\eta_M = 0.4$. If the porosity is measured, a more accurate value can be obtained, although measurement is not required due to the generally small thickness of the mulch layer

S : Sand depth, in ft. Per CASQA Handbook, a layer of sand beneath the amended soil is added. This layer will be 0.5 ft. thick.

η_S : Sand porosity. It is assumed that the porosity of the sand is in the typical range of 0.3 to 0.38. A value of 0.36 was assumed.

G : Gravel depth, in ft. Per CASQA Handbook, a layer of gravel beneath the sand is added. This layer will have a minimum thickness of 0.67 ft, and it should increase in thickness as the french drains (if any) move downstream. If no french drain is provided the thickness remain constant. For calculation purposes, the thickness is assumed constant and equal to 8 inches. The top of the gravel layer is horizontal.

η_G : Gravel porosity. It is assumed that the porosity of the gravel is in the typical range of 0.36 to 0.42. A value of 0.40 was assumed.

T : Total depth (ft.) of the biocell from the bottom of the gravel layer to the top of the mulch. Usually a value of 5 ft. is used, unless drainage constrains force to reduce it to 4.5 ft. or 4 ft. in some of the biocells.

S_0 : Soil depth in ft. It is simply calculated as $S_o = T - M - S - G$. Corresponds to the amended soil depth, complying with the soil mixture properties described above.

η_{So} : Porosity of the soil. According to Appendix A of the El Monte Geotechnical Report prepared by Krazan & Associates, for the Expansion Index Test and the Laboratory Compaction Curve performed only in Boring B-2 the porosity of some soil samples there can be calculated. The minimum and most conservative value obtained was 0.31, and therefore it was the value assumed in the calculation that will follow.

w : Soil water content (fraction of saturation). For all granular materials (gravel, sand, and mulch) the soil water content at the beginning of the water quality storm will be assumed equal zero percent (all voids can be filled by the runoff coming to the biocells). For the amended soil such approximation is not realistic, because the soil will have trapped water due to irrigation (water can escape easily from granular materials but not from soil mixtures). For the biocells that are not large enough compared to its drainage area (less than 1.5 percent of their drainage areas, Biocells 3, 4 and 7) w is assumed 75 percent, and for all others w is assumed 50 percent.

F_P : Infiltration capacity of the soil mixture (in/hr). The infiltration capacity was taken equal to the saturated hydraulic conductivity value from a test performed in a silty sand (SM) sample obtained near the location of Biocell-6. The value obtained was 0.98 in/hr. Infiltration results from unsuitable soils (sandy silt with clay and clayed silt) were not considered. See section of in situ soil types suitable for amended mixture.

SF : Safety factor for infiltration capacity. According to Draft LAC Stormwater BMP Manual, on infiltration basins, the lowest value of infiltration should be divided by 2 (multiplied by 0.5) when determining the required area of infiltration. Therefore, a SF value of 2 has been incorporated in the calculations to account for uncertainty on infiltration of biocells without french drains (Biocells 2, 3, and 4). If french drains are provided, SF=1 because the french drain will take any excess of water unable to infiltrate beneath the biocell.

Equations:

$$V_{BC} = V_P + V_{MGS} + V_{So} + V_I \tag{1}$$

Where:

V_{BC} : Volume treated by the Biocell (ft^3)
V_P : Ponding volume (ft^3)
V_{MGS} : Volume retained in the mulch, gravel and sand (ft^3)
V_{So} : Volume retained in the soil (ft^3)
V_I : Volume infiltrated in 24 hour (during the occurrence of the 24-hr storm event, ft^3)

Using volumetric relationships, the following volumes can be easily obtained:

$$V_P = \frac{(A_T + A_B)P}{2} \tag{2}$$

$$V_{MGS} = A_T\left(M\eta_M + G\eta_G + S\eta_S\right) \tag{3}$$

$$V_{So} = A_T S_o \eta_{So}(1 - w) \tag{4}$$

Using Darcy's Law, neglecting the infiltration through the walls, and assuming saturated conditions beneath the biocell and vertical movement of the water, the following simplified version of the Darcy's equation can be written:

$$V_I = \frac{F_P}{12 \cdot SF} T A_T \tag{5}$$

where:

T : Duration of infiltration during the 24 hr storm event (hr). The water takes some time to reach the bottom of the biocell, and that time must be subtracted to 24 hr. to obtain the time during which infiltration is occurring while raining.

$$T = 24 - \frac{S_0}{v_i} \quad (6)$$

where:

v_i : Velocity at which the water penetrates the amended soil (ft/hr), filling the voids containing air. This velocity can be obtained using the continuity equation.

$$Continuity : v_i \eta_{So} (1-w) A_T = \frac{F_P}{12} A_T \quad therefore :$$

$$v_i = \frac{F_P}{12 \cdot \eta_{So}(1-w)} \quad (7)$$

In the continuity equation F_P represents the infiltration capacity of the amended soil, assumed equal to the value measured for the existing soils in situ without dividing it by the safety factor because the soil will be amended to have at least 45 percent to 60 percent of sand and 1.5 to 3 percent of organics with less than 12 percent of clay.

According to the soil triangle, such a soil have an expected permeability value of at least 0.99 in/hr for the worst case scenario (sand 45 percent, organics 1.5 percent, clay 12 percent) and as high as 2.95 in/hr for the best case scenario (sand 60 percent , organics 3 percent, clay 5 percent). Therefore, a value of F_P = 0.98 in/hr as measured represents the minimum expected value for the permeability of the amended soil.

It is important to note that if french drain is provided, the SF in equation (5) is 1 (any excess of water that the bottom soil can not carry will be leaving through the french drain). When this occurs, the total volume treated by the biocell is independent of the moisture content w and the porosity η_{So} of the amended soil. Thence, the amount V_{So} + V_I can be easily simplified with equation (8) as follows:

$$V_{So} + V_I = 2F_P A_T \quad if \quad SF = 1 \quad (8)$$

Equation (8) can be easily demonstrated substituting (7) in (6) and the result in (5) and adding this result to (4):

$$V_{So} + V_I = A_T S_o \eta_{So}(1-w) + \frac{F_P}{12 \cdot SF}\left(24 - \frac{S_0}{\dfrac{F_P}{12 \cdot \eta_{So}(1-w)}} \right) A_T =$$

$$A_T S_o \eta_{So}(1-w) + F_P \left(2 - \frac{S_0 \eta_{So}(1-w)}{F_P} \right) A_T = A_T S_o \eta_{So}(1-w) + 2F_P A_T - A_T S_o \eta_{So}(1-w) =$$

$$2F_P A_T \quad therefore \quad V_{So} + V_I = 2F_P A_T$$

The following Table presents the detailed results of the biocells treatment volumes and the total volume each biocell is able to treat.

Biocells Water Quality Volume Tabulations

Property	Biocell 1	Biocell 2	Biocell 3	Biocell 4	Biocell 5	Biocell 6	Biocell 7	Biocell 8	Biocell 9
Top Area, A_T (ft^2)	1372	306	311	681	1538	870	601	767	593
Bottom Area, A_B (ft^2)	965	200	199	486	1156	654	388	520	376
Ponding [(1)], P (ft.)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mulch depth, M (ft.)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Gravel depth, G (ft.)	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Sand depth, S (ft.)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Amended soil, S_o (ft.)	3.58	3.58	3.58	3.58	2.58	2.58	3.58	2.58	3.08
Total, (ft^2)	5.00	5.00	5.00	5.00	4.00	4.00	5.00	4.00	4.50
Porosity of Mulch, η_M	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Porosity of Gravel, η_G	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Porosity of Sand, η_S	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Porosity of Soil, η_{So}	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Soil water cont, w (percent)	50	75	75	50	50	50	75	50	50
Infiltr. Cap[(3)], F_p (in/hr)	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
SF for infiltration [(4)]	1.00	2.00	2.00	2.00	1.00	1.00	2.00	1.00	1.00
Inf. Velocity, v_i (ft./hr)	0.52	1.04	1.04	0.52	0.52	0.52	1.04	0.52	0.52
Hr of inf during rain, T	17.1	20.6	20.6	17.1	19.0	19.0	20.6	19.0	18.1
Vol Ponding, V_P (ft^3)	584.3	126.5	127.5	291.8	673.5	381.0	247.3	321.8	242.3
Vol Mulch+Gr+Sd, V_{MGS} (ft^3)	750.0	167.3	170.0	372.3	840.8	475.6	328.5	419.3	324.2
Vol Soil [(5)], V_{SO} (ft^3)	762.0	85.0	86.4	378.2	615.8	348.4	166.9	307.1	283.4
Vol infiltr.[(5),(6)], V_I (ft^3)	1899.6	254.3	258.5	471.5	2367.9	1339.4	499.5	1180.9	867.0
Total Volume (ft^3)	**3996.0**	**633.1**	**642.4**	**1513.7**	**4498.0**	**2544.4**	**1242.2**	**2229.0**	**1716.8**

Notes:

(1): Ponding depth is measured from top surface of biocell (top of mulch) to invert of outlet structure
(2): Total refers to the total depth of the solid phase of the biocell (does not include ponding depth).
(3): Infiltration capacity value selected is the minimum value measured for in situ soil at a depth of 5 ft. For the amended soil, the same value is used.
(4): Security factor for infiltration at the biocell bottom is 3, if no french drain is provided, and if a french drain system is included. For the amended soil SF=1 since the mixture is 50 percent sand
(5): The volume of infiltration through the walls of the biocell is neglected.
(6): $V_{So} + V_I$ is independent of w and η_{So} if SF is 1 for the bottom soil, and if F_p is assumed equal for the amended soil and the bottom soil

A-3 Design Criteria For Underground Infiltration Basins

The UIB is not subject to a BMP analysis in either the Draft LAC Stormwater BMP Manual or the CASQA Handbook. Therefore, some design criteria considerations pertinent to open surface infiltration basin will be included in the design of the UIBs.

A-3.1 Selection of UIB Type

The UIB can be made of many types of materials including: perforated pipes surrounded by gravel, parabolic high-strength plastic sections open at the bottom and surrounded by gravel, highly porous tank module units with no gravel requirements in between, and many other options.

Due to the space limitation, the amount of pipes conflicting with the underground system (new sewer pipes will be added to the design), and the level of design required at this stage to present a detailed solution, Adams Engineering decided to select one of the alternatives mentioned above. The tank module option was selected due to the small footprint it generally generates and the minimum volume it occupies due to its very large porosity.

A-3.2 Design considerations

1. The soil infiltration rate at the bottom of the UIB should be 0.5 in/hr or larger.
2. The underground infiltration basin should be sized in such a way that the entire water quality volume is infiltrated in 48 hrs after the storm, or 72-hr from the beginning of the 24-hr storm event.
3. Cleaning down-spots (8" PVC pipes) will be placed each 50 ft. to have the possibility of vacuum the accumulated fines in the bottom of the UIS.
4. The underground infiltration basin should safely pass the 50-yr. storm event, so the outlet pipes should have a capacity similar to the 50-yr peak flow (some peak flow reduction will be obtained since it takes some volume to fill the UIB from the invert elevation of the outlet pipes to the level at which those outlet pipes can discharge the incoming flow).

A-3.3 Maximum allowable depth

The maximum allowable depth can be obtained with the continuity equation applied for vertical flow infiltration, taking into account the porosity of the Tank Modules:

$$Continuity : H\eta_T A_B = t\frac{F_P}{12SF}A_B \quad therefore :$$

$$H = \frac{tF_P}{12 \cdot \eta_T SF} \qquad (9)$$

where:

H : Depth of the water in the UIB (ft.)

η_T : Porosity of the tank module system (0.95)

t : Time required to drain the depth H (in hours), neglecting the enhancement of infiltration due to change in depth (constant discharge through infiltration). Infiltration will start as soon as the rain starts, because the time of concentration to reach the bottom of the UIB (few minutes) is negligible compared to the storm duration (24-hr). Therefore, the maximum h will be associated with 72 hour (drawdown time of 48 hr after the storm ends).

F_P : Infiltration capacity of the soil beneath the UIB (in/hr). The value FP is taken from the permeability test for a silty sand shown in the Geotechnical report (0.98 in/hr).

SF : Security factor for the infiltration. According to the Draft LAC Stormwater BMP Manual and the CASQA Handbook SF=2 (or k=1/SF = 0.5)

A_B : Area of the base of the Tank Module (sq. ft)

The maximum depth of the water in the UIB is 37" (3.08"). The invert elevation of the outlet pipes should be placed 37" above the bottom of the underground system (the bottom equal to the surface elevation of the lower face of the tank module). The volume of water that can be retained in the gravel bedding (12" thick, and therefore approximately 4-5" of water) will be neglected and accounted as an additional safety factor.

The systems will be three cells height (4.30 ft.) to accommodate the 3.08 ft. of retention plus the 12 inch-outlet pipe above the retention system.

A-3.4 Area of the Underground Infiltration Basin

The required area of the underground infiltration basin can be determined as:

$$A_{B-R} = \frac{(V_{BMP} - V_{BIO})}{\eta_T H} = \frac{V_{UIB-R}}{\eta_T H} \qquad (10)$$

where:

V_{BMP} : Volume of BMP based on the criteria selected in this design, for all area draining to the UIB (ft^3)

V_{BIO} : Volume treated by the Biocell (ft^3). Biocells 2 and 3 treat a portion of the volume directed to the UIB-1 (that portion is lost to infiltration and therefore does not reach the UIB-1) and Biocell 7 treats a portion of the volume directed to the UIB-2 and that volume leaves through infiltration or a French drain system and never reaches UIB-2.

V_{UIB-R}: Required volume of the underground infiltration basin (ft^3)

A_{B-R} : Required area of the underground infiltration basin (ft^2)

H : Depth of water in the UIB (ft), already defined with equation (9)

Each underground system is composed of standard tank module cells measuring 16.06"x26.97" (3.008 ft^2). The number of cells selected will be optimum distribution to accommodate the UIB in the available space. The minimum number of cells required is A_{B-R}/3.008 and that number will be adjusted to the area available to accommodate the cells in a rectangular arrangement.

For UIB-1 the minimum number of cells required is 1479 cells in area (4437 total for a 3 cells high system), and due to the size available the best configuration was 17 x 89 x 3, so 4539 cells were provided (102 additional cells).

For UIB-2 the minimum number of cells required is 211 cells in area (633 total for a 3 cells high system), and due to the size available the best configuration was 11 x 20 x 3, so 660 cells were provided (27 additional cells).

The following table shows the detailed results of the UIB volumes required (V_{UIB-R}) and provided (V_{UIB-P}), as well as the required and provided areas (A_{B-R}, A_{B-P}):

UIB Water Quality Volume Tabulations

Name	UIB-1	UIB-2
Contributing Areas*	1B, 2 to 6 and 8	11
Drainage Area (acres)	6.03	1.39
Q_{WV} (ft^3) of contributing areas	14311	3085
V_{Bio} (ft^3) (already treated)	1282	1232
V_{UIB-R} (ft^3)	13030	1853
H (ft.)	3.08	3.08
A_{B-R} (ft^2)	4448	633
Min no. of biocells required	4437	633
Cell configuration:	89 x 17 x 3	20 x 11 x 3
Number of biocells provided	4539	660
A_{B-P} (ft^2)	4551	662
V_{UIB-P} (ft^3)	13331	1938

* : Area 11 only contributes for storms larger than the 85th percentile storm

A-4 Water Quality Peak Flow Q_{BMP} for Inlet Inserts and the Filter of the Trenches

The Los Angeles County MS4 Permit, (Regional Board Order No. 01-182, NPDES Permit No CAS004001) has three numerical design criteria for flow based BMPs:

1. The flow of runoff produced from a rain event equal to at least 0.2 in/hr intensity or

2. The flow of runoff produced from a rain event equal to at least two times the 85th percentile hourly rainfall intensity for Los Angeles County. or

3. The flow of runoff produced from a rain event that will result in treatment of the same portion of runoff as treated using volumetric standards above

Meetings with staff of the California Regional Water Quality Control Board, Los Angeles Region, and based on our expertise in inlet design, Adams Engineering have determined that inlet inserts and filter trenches more likely will have more than enough capacity to treat the water quality peak flow since those inlets have been designed to deal with extreme events (50 yr peak flow). The expected value of the 50 yr peak flow is usually more than one order of magnitude larger than the expected value of the water quality peak flow, and since the treatment capacity of inlet inserts is around 50% of its total capacity, it is expected that inlet inserts and filter trenches have more than enough capacity of treatment. For this reason, design volume criterion 1 was not used, because it usually produces the smallest water quality peak flow. In this report criterion No. 2 was selected to demonstrate that inlet inserts and filter trenches are large enough to treat the water quality peak flow even when the most stringent criteria is used.

The following is a list of the storm drain inlets (inlets) and storm drain trench to be provided with inlet inserts and trench filters (trench):

a) Inlet 2: draining Area 4 directly to UIB-1
b) Inlet 3: draining Q_{WV} volume not treated by Biocell-2 (Area 5) to UIB-1
c) Inlet 4: draining Q_{WV} volume not treated by Biocell-3 (Area 6) to UIB-1
d) Inlet 5: draining storms larger than 0.75" from Biocell-4 (Area 7) to UIB-1 (Biocell-4 can handle the Q_{WV} volume, but its proximity to the underground made its connection to it very practical)
e) I-8: draining Q_{WV} volume not treated by BC-7 (Area 11) to UIB-2
f) Trench-1: draining Area 2 (truck load area) to UIB-1
g) Trench-2: draining half of the area under the canopy of the gas station (50 percent of A-1B) directly to the drain system in case of a spill (peak flow identical to that of Trench-2)
h) Trench-3: draining half of the area under the canopy of the gas station (50 percent of A-1B) directly to the drain system in case of a spill (peak flow identical to that of Trench-2)

All those inlet-inserts and trench filters require the determination of the Q_{WV} to ensure that the BMP provided has enough treatment capacity to handle the flow from the 0.75" storm event.

Regarding inlets-1 (located in Biocell-1), Inlet-6 (located in Biocell-5), Inlet-7 (located in Biocell-6), Inlet-9 (located in Biocell-8) and Inlet-10 (located in Biocell-10), no inlet inserts are needed because the biocells where they are placed have enough capacity to treat the 0.75-inch rainfall event. Only a screen will be provided in those inlets to avoid trash entrance to the drainage system in case of a large event.

In order to determine the Q_{BMP} of the inlets inserts using criterion 2, the following information is needed:

- Area draining to each inlet (acres)
- Fraction impervious and pervious of the area
- C coefficient based on soil type and fraction impervious
- Time of concentration based upon longest water path (ft) and difference in elevation for the water path (ft)
- Intensity based upon the time of concentration (in/hr)

The attached table (Water Quality Mitigated Flow Table shown at the end of the mathematical explanation that follows) shows the area, time of concentration calculations, intensity calculations, C calculations and flows (Q).

The sequence of calculation is the following:

The soil type was determined using the Hydrologic Map 1-H1-20 of the LA County Hydrology Manual, with the site location. The soil type is 015, corresponding to Tujunga Fine Sandy Loam with a C coefficient for impervious areas C_u expressed as a function of the intensity.

According to equation (1), a mathematical representation of the Runoff Coefficient Table No. 15, Appendix D-6:

$$C_u = 0.1 \quad if \quad I < 1.04 in/hr \quad otherwise \quad C_u = 0.3047\ln(I) + 0.0875 \qquad (1)$$

The overall C coefficient C_d is a function of the pervious fraction F_P as:

$$C_d = f_P C_u + 0.90(1 - f_P) \qquad (2)$$

In those equations:

C_d : overall C coefficient for Rational Method
C_u : C coefficient for the pervious fraction
f_P : Pervious fraction
I : Intensity of precipitation (in/hr)

Since the value C_d is a function of the intensity, and the intensity is a function of the time of concentration t_c, this last value must be determined.

The relationship between the intensity and the duration time for a 0.75 inch rainfall for all zones (the design criteria of the Q_{BMP} in Los Angeles County) is shown in Table B-1 of the Draft LAC Stormwater BMP Manual. This value must be multiplied by two according to flow-based criteria for flow-based treatment BMPs.

As a mathematical expression, the relationship between twice the intensity of the 85th percentile hourly rainfall intensity for Los Angeles County and the time of concentration t_c can be obtained with equation (3):

$$I = 2 \cdot \frac{143}{150} t_c^{-0.47} \quad (3)$$

Since the maximum value of the intensity corresponds with a value of t_c = 5 minutes (minimum value of time of concentration to be used in intensity vs. time equation), then I_{5min}=0.89 in/hr, less than 1.04 in/hr (see equation (1)).

Therefore, for an 85th percentile storm event, the C_u coefficient will be always equal to 0.1 for the existing soil type (it can change for more extreme events when the expected intensity can exceed 1.04 in/hr).

Finally, the value t_c can be obtained with the mathematical expression (4) as a function of C_d, I, L (longest water path) and S (slope for the water path), taken directly from the Draft LAC Stormwater BMP Manual:

$$t_c = 10^{-0.507} (C_d I)^{-0.519} L^{0..483} S^{-0.135} \quad (4)$$

To simplify the calculations, equation (1) for I<1.04 in/hr (Cd=0.1) can be replaced in (2), and equation (2) can be replaced in (4), and the result can be replaced in (3):

$$I = 2 \cdot \frac{143}{150} \left[10^{-0.507} \left((0.1 f_P + 0.9 - 0.9 F_P) I \right)^{-0.519} L^{0.483} S^{-0.135} \right]^{-0.47} \quad therefore:$$

$$I - 3.30 (0.9 - 0.8 f_P)^{0.244} I^{0.244} L^{-0.227} S^{0.0635} = 0 \quad (5)$$

The complex resulting equation (5) has only one unknown (I), and can be solved easily with a spreadsheet, so no iterations are necessary.

After equation (5) has been obtained, the sequence of calculation can be explained now. The value of L and S are determined from the Drainage Area Map. The value f_P is simply the fraction of previous area that can be obtained for the drainage area of each inlet.

An internal iteration from a spreadsheet will determine the value I that satisfies equation (5). Once it has been check the validity of our initial assumption (I less than 1.04 in/hr) the value of Q_{BMP} is simply:

$$Q = C_d \cdot I \cdot A \quad (6)$$

Each Q_{BMP} is shown in the Q_{BMP} Table shown next. It can be seen that the magnitude of Q_{BMP} for all inserts using criteria No. 2 far exceeds the magnitude that would have been obtained using criteria No. 1 since all intensities determined with equation (5) are larger than 0.2 in/hr (see final value of intensity I_{BMP} in the Q_{BMP} Table).

Water Quality Mitigated Flow (Q_{BMP})

BMP	Sub-area	Area (acres)	f_P	L, ft	S	I (in/hr)	C	T_c (min)	Q_{BMP} (cfs)
Trench 2*	50 % of 1B	0.04	0.000	100	0.008	0.78	0.900	6.7	0.03
Trench 3*	50 % of 1B	0.04	0.000	100	0.008	0.78	0.900	6.7	0.03
Trench 1	3	0.13	0.000	150	0.027	0.77	0.900	6.9	0.09
Insert 2	4	0.68	0.063	271	0.013	0.59	0.850	11.9	0.34
Insert 3	5	1.64	0.063	336	0.024	0.59	0.849	12.2	0.82
Insert 4	6	0.98	0.073	300	0.021	0.60	0.842	11.8	0.49
Insert 5	7	0.63	0.192	228	0.017	0.61	0.746	11.2	0.29
Insert 8	11	1.39	0.107	362	0.016	0.55	0.814	14.2	0.62

*: the Q_{BMP} calculated here is assuming that no canopy exists. The peak flow over the canopy will actually be directed to the UIB-1 and Trench-2 and Trench-3 will have a capacity similar of that of Trench-1 and will be placed for emergency purposes only (in case of a spill)

A-4.1 Trench Filter Design and the Inlet Insert Design

The manufacturer's capacity of the trench drain filter Model 5-12 is 0.064 cfs/ft. (capacity per foot of filter). Model 5-12 by Bio-Clean® will be provided to Trenches 1, 2 and 3.

Since the peak flows for Trench-1, Trench-2 and Trench-3 are 0.09 cfs, 0.03 cfs, and 0.03 cfs, respectively, only 1.4 ft, 0.5 ft, and 0.5 ft of the trench filter provides the required capacity to treat the expected Q_{BMP}. Since the trench filter TC-1, TC-2 and TC-3 are going to be 6 ft, 13 ft and 13 ft long, respectively, trench filters have more than 4, 25 and 25 times the capacity required.

The inlet inserts in Inlets 2, 3, 4, 5 and 8 are all the same size. They will be installed with Bio-Clean® filter insert Type-GISB 36-36-25.

These inlet inserts have three level screen systems, a skimmer and a storm boom. The bottom layer of fine screen has a capacity of 10.8 cfs, the medium layer a capacity of 6.4 cfs and the coarse layer has a capacity of 6.2 cfs for a total treated capacity of 23.4 cfs and a throat flow rate of 18.8 cfs that then becomes the limiting factor (the throat discharging into the screens has a lesser hydraulic capacity than the screens itself so it becomes the chocking point).

The Q_{BMP} for Inlets 2, 3, 4, 5 and 8 are 0.34 cfs, 0.82 cfs, 0.49 cfs, 0.29 cfs and 0.62 cfs, respectively. Therefore, the inlet insert has a capacity more than 20 times larger than the maximum Q_{BMP} (18.8 cfs/20 greater than 0.82 cfs), and the fine screen at the bottom has a capacity more than 7 times the larger Q_{BMP}.

The inlets shall be maintained regularly to perform efficiently and pre-treat adequately the flows discharging into the UIBs.