Criticality of Stormwater Control Measures: Quantification of Potential Failure Impacts to be Used in Inspection and Maintenance Prioritization

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Abstract

The City of Austin has developed a method for addressing the growing need for infrastructure asset management for flood and water quality control facilities. The City requires that these facilities, primarily stormwater control facilities or "ponds", be constructed to offset the impacts of development on watershed functions. In addition, the City itself constructs facilities on a regional basis (flood control ponds) and to treat flood flows and washoff pollutants in areas that were developed before controls were required. The asset management approach described in this report for water quality and flood control ponds is a condition-criticality matrix, which will allow the prioritization of City-maintained ponds that will both minimize the likelihood and effects of pond failure. This paper addresses only the criticality approach for both flood and water quality controls; these criticality components are then added and combined with a condition assessment in an overall prioritization scheme. The criticality factor for stormwater control facilities includes consideration of downstream impacts, the amount of protection provided, potential human impacts and sensitive environmental features that may be affected.

In Proc: Texas AgriLife Research. 2011 Intl SWAT Conf, Toledo Spain. June, 2011.
http://swat.tamu.edu/media/49257/conference-proceedings.pdf

Introduction

Although stormwater control infrastructure has been growing along with the City of Austin's (COA) rapid development, aging and potential failure of the existing systems is a concern in older areas of the city. The COA Watershed Protection Department (WPD) is developing an asset management (AM) program for the drainage infrastructure it owns, operates and/or maintains. Management of this infrastructure is critical to all three of WPD mission areas (flood hazard mitigation, erosion prevention and water quality protection). A robust AM program will allow proactive allocation of resources to maintain desired levels of service while minimizing life cycle costs. In particular, the hundreds of existing stormwater control measures (SCMs) may provide protection for all three missions. Figure 1 shows the growth in number and age of the SCMs maintained by COA. Maintenance components may differ between green and more traditional grey infrastructure; Appendix A includes the general features evaluated currently for the assessment of the condition of SCMs.

This paper will address the criticality component of the approach developed in order to prioritize maintenance and rehabilitation. It will be used in a systematic approach based on both the condition of the facilities and the criticality if failure were to occur that is both efficient and reproducible; as a result of the need for spatial specificity, geographical information system (GIS) processing tools were used where possible. The condition is determined by the field crews tasked with maintenance as shown in Appendix A. The ranking system to help determine asset management prioritization that combines the condition and criticality of failure is shown in Figure 2. For all ranking systems, they are reduced to a number between 1 and 5 for the purposed of prioritization, with the value of 5 being the highest and 1 being the lowest.

Figure 1. Cumulative, annual numbers and projected numbers of SCMs (ponds) maintained by the City of Austin Watershed Protection Department (WPD) over time

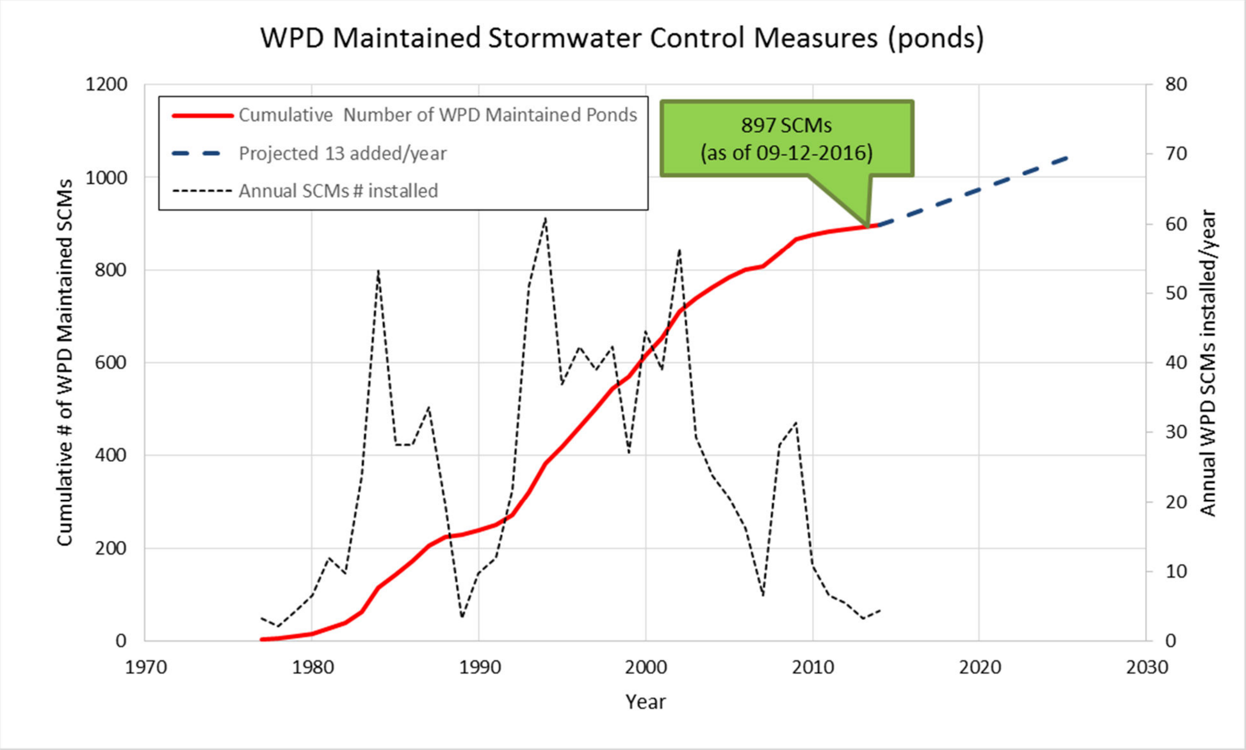
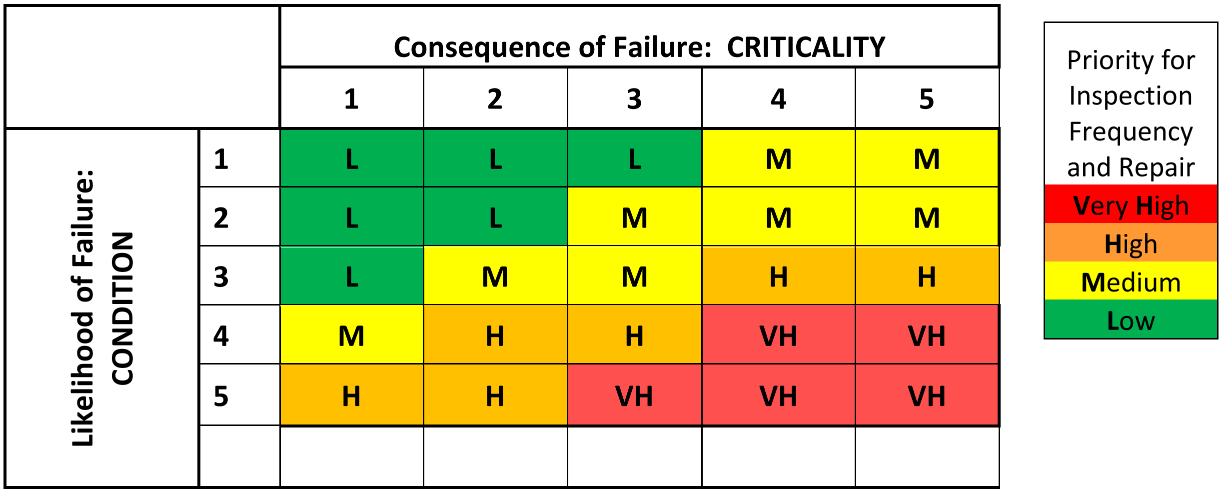


Figure 2. Prioritization through Condition Criticality Matrix



Likelihood of Failure: CONDITION	Consequence of Failure: CRITICALITY 1	2	3	4	5
1	L	L	L	M	M
2	L	L	M	M	M
3	L	M	M	H	H
4	M	H	H	VH	VH
5	H	H	VH	VH	VH

Priority for Inspection Frequency and Repair
🟥 Very High
🟧 High
🟨 Medium
🟩 Low

Method: Flood Control Criticality

The consequence of failure for flood control functions of SCMs assesses four potential risk criteria:

1) if any part of the detention pond is a dam regulated by the Texas Commission on Environmental Quality (TCEQ),
2) critical infrastructure as identified by COA Emergency Management that is located downstream of the SCM (C),
3) possible inundation of buildings located downstream of the SCM (BD), and
4) potential roadway inundation located downstream of the SCM (SD).

In order to determine what would be considered "downstream" of a pond, WPD developed a GIS method for identifying a potential risk area (PRA). The methodology for the PRA does not involve any hydrologic or hydraulic modeling, but uses standard COA simplified dam analysis methodology and general engineering guidelines to create a moderately conservative PRA. The main concept that was adopted from the COA simplified dam breach analysis is dam breach length. A modified version of this length is used in the PRA as the distance that the PRA extends away from the SCM. The first step in developing a PRA is to create a buffer around the detention pond. The equation that is used for a simplified dam breach analysis is:

$$L = 0.012K\sqrt{2CH}$$

Where L is the length of the breach in miles, C is the volume of the pond in acre-feet, H is the maximum interior height of the pond in feet, and K is a correction factor for the spillway size (for the PRA this is assumed to be 1.8).

Once the length has been determined, the PRAs were created to delineate the areas that are downstream of the pond within the buffer length. A step-by-step workflow for producing PRAs is provided in the COA method "Potential Risk Area Creation" provided in Appendix B; the procedure is done using a series of tools from the ESRI ArcGIS Toolboxes including 3D Analyst Tools, Spatial Analyst Tools, and Analysis Tools. Once the PRA has been delineated, the critical infrastructure, number of buildings, and length and type of roadways that are within the PRA are identified.

The consequence of failure is ranked based on a combination of a TCEQ rank, a C rank, a BD rank, and a SD rank. Table 1 shows the classification breakdown for each rank on the 1 to 5 criticality scale with a 5 indicating the most critical structures.

- The TCEQ rank is based on the presence of a TCEQ dam as part of the SCM and is either a yes or no (5 or 1).
- The C rank is based on the presence of any critical infrastructure as identified by COA Emergency Management located within the PRA.
- Criticality of structures and transportation within the PRA is evaluated by averaging the building area (BD rank) and a weighted street area (SD rank) as described following Table 1. The BD rank is based on the building-foot equivalent of the buildings that are located in the PRA. And the SD rank is based on the weighted street-foot equivalent of the streets that are located in the PRA, the weighting and street-foot equivalents are described below and in Table 2.

Since the PRA was not developed using hydrologic or hydraulic modeling, there is a need to approximate the severity of the flooding in each PRA and create the building-foot equivalent and weighted street-foot equivalent units. The depth of water across the PRA is approximated by dividing the pond volume by the area of the PRA. This depth is then multiplied by the number of buildings and the weighted length of roadways to determine the building-foot equivalent and the weighted street-foot equivalent for each PRA. The street ranking is further weighted by the type of street. The weighting factors in Table 2 below are multiplied by the length of roadway within the PRA and then all weighted street lengths are added together before calculating the weighted street-foot equivalent for the PRA.

Table 1 – Flood Control Criticality Ranking Components

Ranking	TCEQ Rank (TCEQ Dam)	C Rank (Critical Infrastructure)	50%(BD Rank) + 50%(SD Rank)	
			BD Rank (Building-Foot Equivalent)	SD Rank (Weighted Street-Foot Equivalent)
1	Detention pond does not include a TCEQ regulated dam	No critical infrastructure in the PRA	0	0
2	-- -- -- -- --	-- -- -- -- --	≤1	≤5,000
3	-- -- -- -- --	-- -- -- -- --	1<x≤5	5,000<x≤25,000
4	-- -- -- -- --	-- -- -- -- --	5<x≤20	25,000<x≤100,000
5	Detention pond **DOES** include a TCEQ regulated dam	There is at least one piece of infrastructure that is considered critical in the PRA	>20	>100,000

Table 2 - Weighting factor for street lengths

Roadway Classification	Weighting Factor
Interstate, Fwy, Expy, Toll	100
US and State Highways	100
Major Arterials and County Roads (FM)	100
Minor Arterials	50
Local City/County Street	50
City Collector	50
Ramps and Turnarounds	50
Cul-de-sac	50
Private Road	1
Routing Driveway/Service Road	1
Driveway	1
Alley	1
Platted ROW/Unbuilt	Not Included
Unimproved Public Road	Not Included

Once each rank has been classified, the maximum value between the TCEQ rank, the C rank, and the averaged BD and SD rank is the consequence of failure ranking for the detention pond.

$$Flood\ Control\ Criticality\ Ranking = Max(TCEQ\ Rank, C\ Rank, \frac{BD + SD\ ranks}{2})$$

Method: Water Quality Criticality

The consequence of failure assessment for water quality ponds is based on four criteria:

1) potential pollutant load released on failure,
2) a load sensitivity factor based on whether the receiving creek is already impaired or if sensitive groundwater areas were impacted,
3) erosion potential or the loss of erosion protection on the downstream creek reaches, and
4) an erosion sensitivity factor based soils within the ecoregion.

For each SCM, the relative pollutant load released is calculated based on an estimate of the annual load captured as a function of pond volume (V), drainage area (A), impervious cover (C), and pond type. There is an assumed drawdown time (DDT) for each pond type. There are separate load calculations for sedimentation-filtration basins, stand alone sedimentation basins, rain gardens and retention-irrigation ponds, from a statistical relationship between the variables and a load calculated by the Adams & Papa model (Adams and Papa 2000). Several assumptions are made where data is lacking. Where there is no control volume, a capture volume of ½-inch is assumed for consistency with current COA regulations. For control structure types that do not have a load equation, it is assumed that they function as if they were a sedimentation-filtration pond. The equations for each SCM type are provided below:

Rain garden, annual load captured (lbs/yr):

$$(-0.0577V^2 + 0.3115V - 0.23 + 0.0125V^2C - 0.0569VC + 0.0897C - 0.0005V^2C^2 + 0.0018VC^2 - 0.0004C^2) * (\frac{A}{5})$$

Retention/Irrigation pond, annual load captured (lbs/year):

$$(-1.0916V^2 + 6.3723V + 80.223 + 0.283V^2C - 1.3128VC + 17.502C - 0.0352V^2C^2 + 0.1243VC^2 - 0.0818C^2) * (\frac{A}{1000})$$

Sedimentation pond, Annual load captured (lbs/year):

$$(-0.853V^2 + 4.1824V + 33.744 + 0.2088V^2C - 0.8629VC + 7.8203C - 0.0146V^2C^2 + 0.053VC^2 - 0.0355C^2) * (\frac{A}{1000})$$

Sedimentation/Filtration pond, annual load captured (lbs/year):

$$(2.5912V^2 + 10.233V + 57.063 + 0.5206V^2C - 1.997VC + 13.703C - 0.0284V^2C^2 + 0.0992VC^2 - 0.0858C^2) * (\frac{A}{1000})$$

For each pond, the PRA was defined based on an estimate of area inundated from a failed dam as described in the preceding section on the flood criticality score. The sensitivity factors for released pollutant load is based on whether released pollutants might impact PRAs that contain sensitive groundwater features (e.g., caves or sinkholes) delineated in COA GIS resources or whether the drainage area to the pond is within an impaired creek reach. The impaired creek reach sensitivity score is based on the COA Water Quality Problem Score (COA 2009) which was developed to prioritize areas where SCMs would improve creek health. The load sensitivity factor is the maximum of these factors (Table 3).

Table 3 - Sensitivity factor for load impacts = max of a. and b.

a. Sensitive features in PRA	**Sensitivity Factor**
Significant Recharge Feature in PRA (sinkhole, etc.) as provided by COA geologists	10
PRA intersects Recharge Zone	4
PRA intersects Contributing Zone	2
No Sensitive features	1
b. Drainage Area Reach Sensitivity	Water Quality Problem Score/20

The Erosion Potential factor from a failed SCM evaluates the protection provided by the SCM, which is a product of the ratio of Pond Volume (V) to the Stream Protection Volume (SPV) times the drainage area (DA); the Stream Protection methodology is described in HDR (2011). The product of V times SPV has a maximum value of 1 indicating that the SCM volume is sufficient to protect the stream from erosion in the case of SCM failure.

$$Erosion\ Potential\ (EP) = Max\left(\frac{V}{SPV}, 1\right) * DA$$

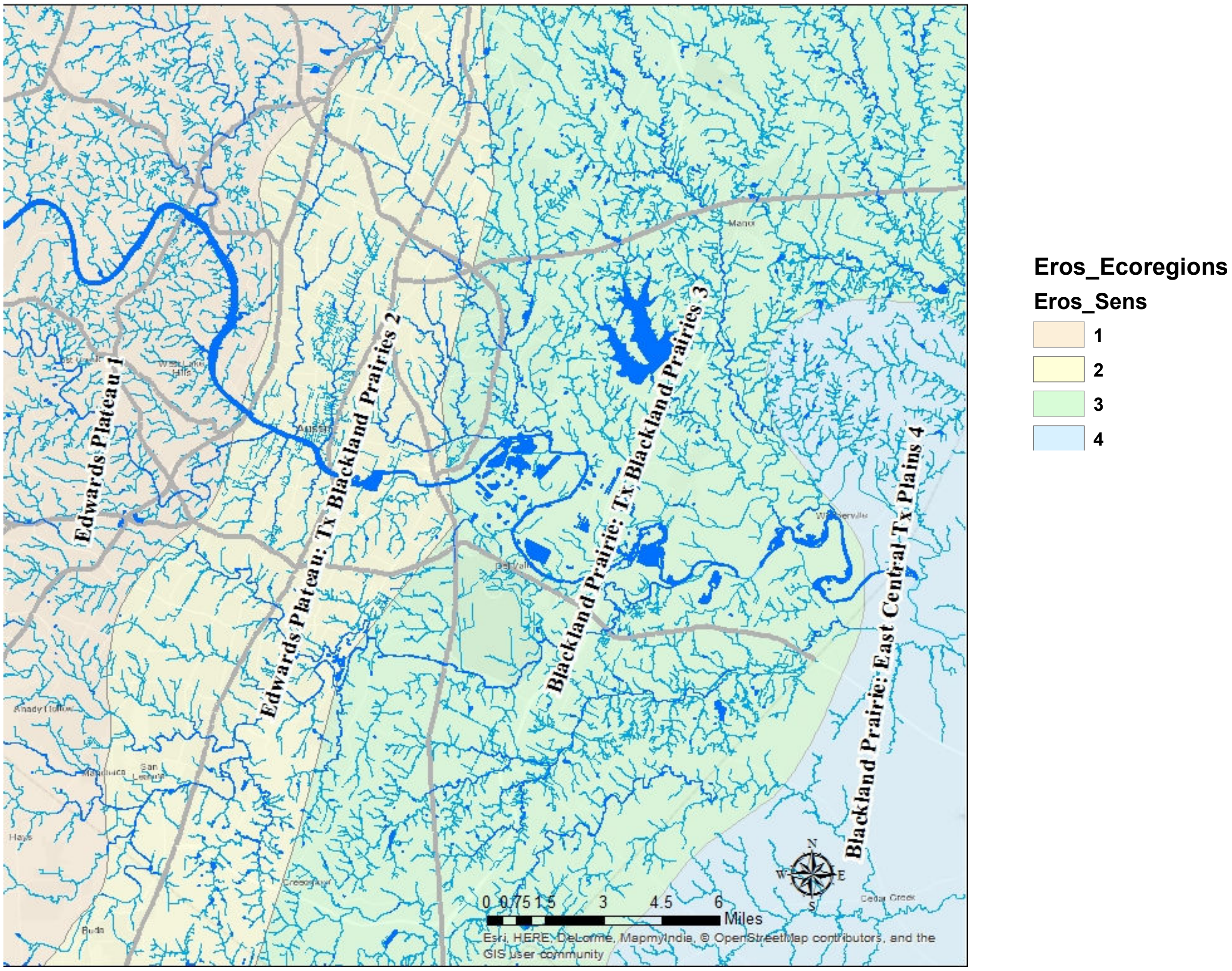
The Erosion Sensitivity factor is based on the soil type, a surrogate for erodibility of the creek bed and bank materials, as determined from Austin combined ecoregions (Figure 3) within the PRA. The Austin combined ecoregions were developed by intersecting U.S. Environmental Protection Agency Level3 regional maps (EPA accessed November 2017) with the Texas Parks and Wildlife Department Natural Regions map (TPWD accessed November 2017), providing a sensitivity gradient that varies from highly erosive in the East Blackland Prairie region to fairly resistant in the Edwards Plateau region to the west (Table 4).

Table 4. Erosion Sensitivity (ES) based on Ecoregion

Austin Combined Ecoregion*	PRA Score
Blacklands: East Central TX	Max (4)
Blacklands: Texas Prairies	High (3)
Blacklands: Edwards Plateau	Med (2)
Edwards Plateau	Low (1)

*Overlay with both EPA and TPWD Descriptive Titles.

Figure 3. Austin Area Ecoregions: Erosion Sensitivity Zones



The water quality consequence of failure ranking, or criticality, for each SCM combines the pollutant load (PL), water quality environmental sensitivity (WS), erosion potential (EP), and erosion sensitivity (ES). Because the raw scores were not yet set on a scale of 1 to 5, the maximum erosion criticality score was multiplied by a factor of 0.6 so that the range of erosion criticality (EP * ES) and load criticality (PL * WS) were the same, thus weighting them in a similar manner. The sum of these scores then needed to be converted to the 1 to 5 scale. The power function with a radical exponent was used to scale the highly skewed results to the scale of 1 through 5 and values were rounded down to an integer value, not less than one. The exponent used for the power function was 0.24, or approximately the 4th root of the total water quality criticality.

$$Water\ Quality\ Criticality\ Rank = (\ PL * WS + 0.6 * EP * ES)^{0.24}$$

Method: Overall Criticality Score and Rank

Some SCMs are designed to provide both flood control and water quality functions. For SCMs designed to provide both flood and water quality protection functions, the overall score was the maximum criticality score either for flood or water quality. This criticality rank must be combined with a condition score to determine priority for maintenance. The condition ranking forms are provided in Appendix A.

Analysis/Results

The distribution of criticality scores both for the water quality criticality and the flood control criticality rankings, as well as for the total criticality rank are shown in Figure 4. The conversion of scores to the ranks considered both descriptive criticality definitions (e.g. when criticality rank is very high will a failure of those SCMs lead to costly damage or repairs?) the capacity of COA maintenance crews to inspect and address the most critical ponds within a reasonable time frame. These considerations led to the classification breaks for flood criticality and selection of the power function in converting scores to 1 to 5 rankings. The resulting distribution of criticality scores was skewed towards the lower ranks; this was an anticipated result supported by the fact that many SCMs have small volumes or have few structures in their PRAs.

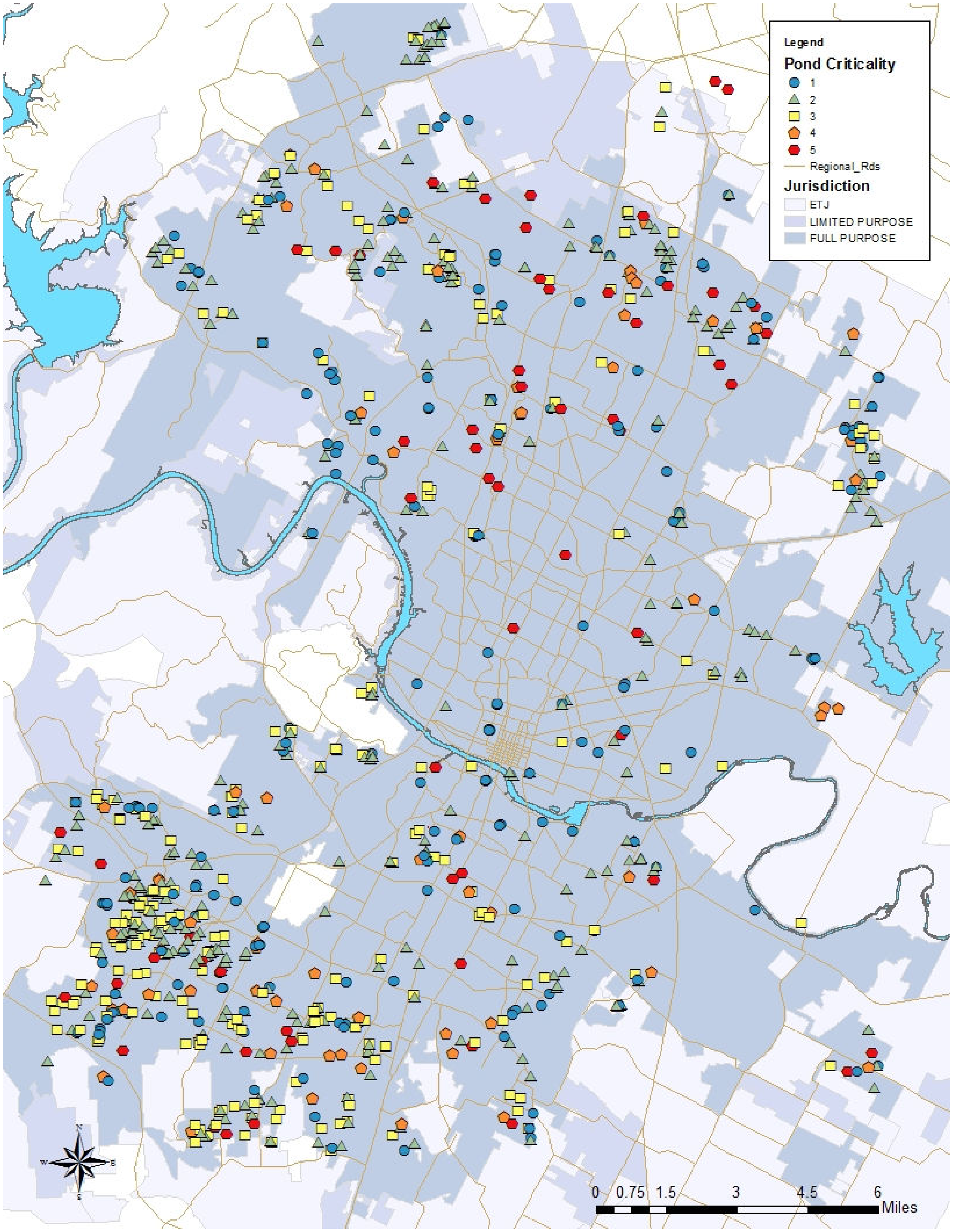
Spatial distribution was also examined for the overall criticality scores. The geographic distribution, shown in Figure 5 reflects the various impacts that were included in the analysis. Austin soils and erosive vulnerability are higher in the eastern areas, while recharge features and groundwater sensitivity are higher towards the west (Figure 5). There may be some geographic bias because of lack of regulations requiring SCMs when the central Austin area was first developed; in addition, when condition ratings are included (not shown in Figure 5) those condition ranks may be higher closer to the urban core reflecting the age of the infrastructure.

Figure 4. Distribution of Criticality Rankings

Conclusions

This effort to evaluate the criticality of SCMs that provide flood protection, water quality protection, or both flood and water quality protection, developed a robust and spatially-explicit ranking methods that reflects the potential impacts of failure. The approach is easily replicated using available data on these SCMs. COA is developing methods to ensure that associated data (for example, the drainage area to SCMs and the PRAs) are generated as new facilities that WPD must maintain are added; this step is critical in updating the priorities as condition rankings change. The criticality ranking alone will not determine the prioritization for maintenance, as the other key component is the condition of the SCM. Because WPD resources are limited and the number of SCMs in Austin continue to increase over time, the combined criticality and condition rankings will be used to prioritize inspection of SCMs.

Figure 5. Geographic Distribution of SCF Criticality



References

Adams BJ and F Papa. 2000. Urban Stormwater Management Planning with Analytical Probabilistic Models. John Wiley and Sons, Inc. New York, NY.

City of Austin (COA). 2009. WPDRD Master Plan Water Quality Problem Score Method Revision. City of Austin Watershed Protection and Development Review Department. SR-08-09. http://www.austintexas.gov/watershed_protection/publications/document.cfm?id=186352

Environmental Protection Agency (EPA). 2017. Level III and IV Ecoregions by State . Ecoregion Download Files by State – Region 6. https://www.epa.gov/eco-research/ecoregion-download-files-state-region-6#pane-41. Accessed November 2017.

HDR. 2011. Quantification of the Long-Term Benefits of On-Site Detention for Developing Austin Watersheds: Stream Protection Curve. Prepared for the City of Austin. Prepared by HDR Engineering, Inc. March 2011. HDR-00310-94889-11. http://www.austintexas.gov/watershed_protection/publications/document.cfm?id=206598

Texas Parks and Wildlife Department (TPWD). 2017. Texas Natural Regions, Hill Country. https://tpwd.texas.gov/education/resources/texas-junior-naturalists/regions. Accessed November 2017.

Appendix A: Condition Rating Field Sheets for Structural Control Measures

STORM WATER MANAGEMENT STRUCTURES

CONDITION ASSESSMENT DEFICIENCY IDENTIFICATION

General information

Inspector:	**Date:**	**Maximo Asset #:**	**Pond Type:**

Condition Rating (Deterioration/Damage)

Site & Structural Elements	**Condition Rating**	**Notes**
Inflow Conveyance Pipe or Channel (A)		
Inlet Structure (Inlet/Splitter/Apron) (B)		
Perimeter (Berm/Slope/Wall) (C)		
First Basin Floor (Detention Basin/Sediment Basin/Wet Pond Forebay) (D1)		
Second Basin Floor (Filtration Basin/Permanent Pool) (D2)		
Riser Pipe/Inverter pipe/Trash Rack (E)		
Interior Separator (Wall/Berm) (F)		
Outlet Structure (Flow Control/Pipe/Apron) (G)		
Overflow Spillway (H)		
Outflow Conveyance Pipe or Channel (I)		

Maintenance Work Order Rating

Work Order Elements	**Work Order Priority**	**Notes**
Security and Access		
Vegetation/Mowing		
Blockage/Debris/Trash		
Sediment Build-up		
Standing/Stagnant or Leaking Water		
Vector/Pest Control		
Erosion/Voids		
Pipe/Concrete Repair		

STORM WATER MANAGEMENT STRUCTURES

Condition Rating Factors

DAMAGE/DETERIATION TO LININGS OR OTHER STRUCTURES

1. Minor erosion at inflow, or along trickle channel, or at outfall.
2. Scour causing standing water for less than 96 hours. Berm sag < 6 inches with minor erosion present.
3. Moderate erosion present undercutting a portion of concrete structure, rock displaced, or water standing in scour hole for more than 96 hours. Berm below overflow structure with moderate erosion present. Minor wet pond/RI pond leaking.
4. Severe erosion of side slope. Scour undercutting large portion of concrete structure. Berm sag below overflow structure with severe erosion present. Moderate wet pond/RI pond leaking.
5. Erosion has caused headwall and / or pipe to collapse. Slope failure - erosion is hazard to public in unfenced area. Berm failure - Complete loss of structural integrity.

VOIDS

1. Voids not present, or less than 3 inch diameter
2. Voids less than 1 ft diameter and less than 1 ft deep. Hairline cracks less than 1/8 inch. Active animal burrows.
3. Multiple voids less than 2 ft diameter and 1 ft deep. Active animal burrows at top or exterior slope.
4. Voids greater than 2 ft diameter and 3 ft deep with evidence of seepage. Active animal burrows inside slope or spillway.
5. Large voids with subgrade collapse greater than 3 ft diameter. Any void greater than 1 ft diameter with active leakage.

Condition & Maintenance Rating Factors

CONCRETE

1. Discontinuity of sealer but joint sound. Superficial cracks with no width.
2. Joint closed but sealer decayed. Spalling < 1 sqft. Minor cracks 1/8-1/4 inch wide.
3. Joint partially open, sealer decayed, minor leakage. Spalling 1-5 sqft or 1 inch thick. Cracks 1/4-1/2 inch wide.
4. Open joint with cracking and trickle leakage, multiple cracks > 1/2-1 inch wide. Spalling > 5 sqft or 2 inch thick. Wall leaning or bowing visible.
5. Collapsed/loss of structural integrity. Cracking > 1 inch with considerable leakage or corroded rebar. Spalling > 10 sqft or 3 inches thick exposed rebar.

PIPE CONDITION

1. Joint sealing material loose. Circumferential cracks
2. Joint offset with pipe edges still visible. Top of pipe visibly uncovered. Longitudinal cracks with no gap visible
3. Joint Offset - soil visible , joint is offset, but soil has NOT migrated into pipe. Fractures with gap visible.
4. Pipe is deformed ; shape change (egg -shaped). Fracture Hinges- four longitudinal Fractures at 12,3,6,9.
5. Broken- 1 or more pieces of the pipe area no longer attached. Hole - void visible able to where soil has infiltrated into pipe. Collapsed- complete loss of structural integrity.

Maintenance Rating Factors

VEGETATION

1. Few small scattered saplings growing on berms or basin, good vegetation coverage.
2. Several small/moderate sized saplings growing on berms/basin or near concrete/riprap structures. Bare areas < 10 square feet.
3. Many saplings/small bushes covering 25-50 % of pond area, near concrete/riprap structures partially obstructing flow. Bare areas > 10 sq. ft.
4. Many woodies covering 50- 75 % of pond area, access, or near concrete structures causing structural damage or partially blocking flow.
5. Large woodies covering > 75% of pond, access, completely obstructing flow, near concrete/riprap causing collapse, or buckling or severe wet pond/RI pond leaking.

BLOCKAGE/DEBRIS/SEDIMENT

1. No blockage to 10 % blocked
2. Up to 25% blocked
3. 25% to 50 % blocked.
4. 50 % to 75% blocked. Obstruction is causing standing water for more than 96 Hrs
5. 100% blocked. Standing water more than 96 Hrs. Significant loss of volume due to sediment build up.

SECURITY

1. Fence in good condition and functioning correctly, all pickets in place
2. Fence damaged but still functioning, no risk to public
3. Fence/gate damage with some risk of hazard to public
4. Fence gatae/damage with potential risk of significant hazard to pond
5. Fence/gate absent or not functioning. Immediate risk to public, steep slopes, high traffic area

ACCESS

1. Access Road in place, good condition and can be utilized by all types of necessary equipment.
2. Access road needs work but accessible by all types of necessary equipment.
3. Easement/Road in place but current site constraints allow access by small equipment only.
4. Easement/Road in place but only accessible by foot or ATV only.
5. No road or easement. Pond not accessible for maintenance .

STORM WATER MANAGEMENT STRUCTURES

CONDITION ASSESSMENT DEFICIENCY IDENTIFICATION

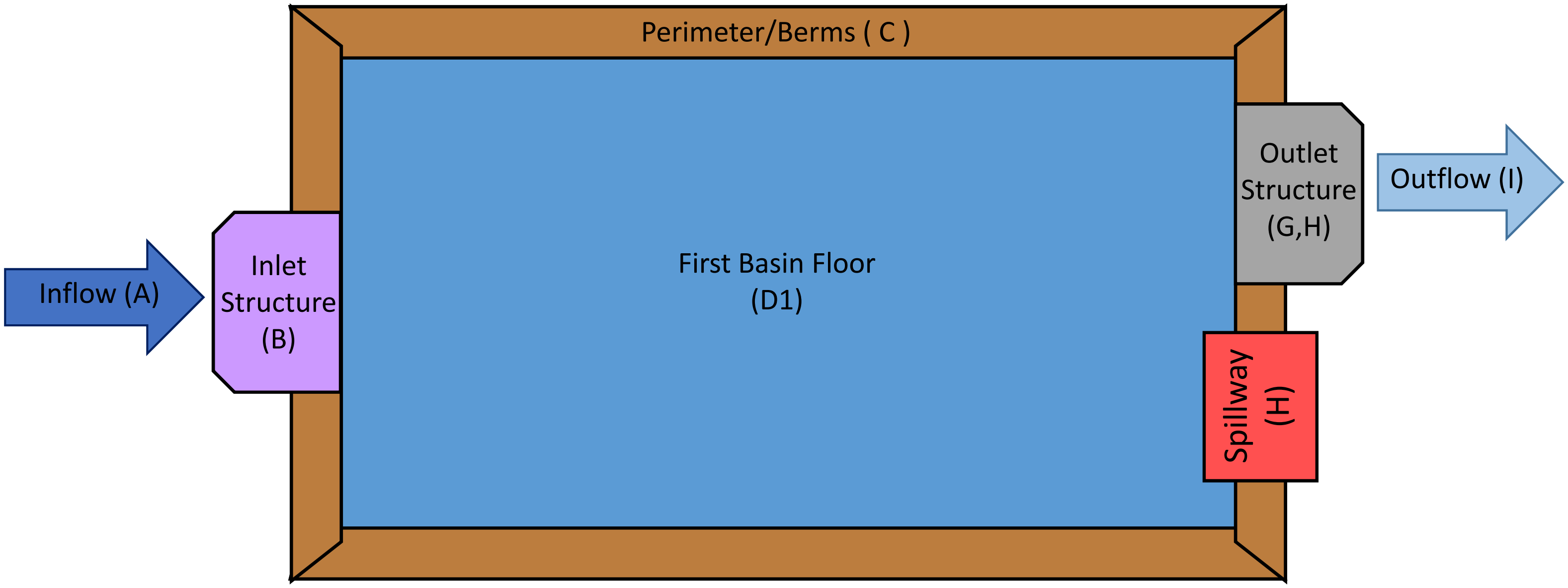
Overall Condition Rating Guidance

Grade	Description	Work Type	Response
0	Asset has been properly decommissioned, no longer exists, or is unable to be rated due to serviceability Issues.	NA	If needed clear access to rate asset
1	Sound physical condition. No notable defects or loss of function/capacity. Asset likely to perform adequately without major work for significant time period.	NA	No problems observed, no work needed at this time.
2	Acceptable physical condition, only minor defects but functions as designed, negligible short-term failure risk.	Preventative Maintenance	Only minor preventative maintenance that does not physically impact the pond (e.g. fence repair, tree trimming, trash pickup, etc.)
3	Moderate deterioration, several defects affecting performance, minor components of the asset may need replacement/repair now, but not affecting short-term structural Integrity.	Light Corrective Maintenance/Repair	Corrective work to address defects that can be readily performed by pond maintenance crews. (e.g. replacing sand, silt removal, fixing erosion, removing sediment etc.)
4	Significant defects evident affecting structural integrity and/or hydraulic performance and pond is not working as designed. Serious deterioration and failure likely in short to medium term. (e.g. settled embankment, clean out cap missing in filter basin, stormwater not accessing pond, etc.)	Heavy Corrective Maintenance	Take immediate action as appropriate to address the defects. Schedule appropriate action - rehabilitation or renewal in short term (heavy pond crew work or contractor). Engineering assistance may be needed.
5	Failed or failure imminent. Either pond is barely functional with serious defects or pond is not functional and major work or renewal, replacement required urgently.	Renewal/Rehabilitation	In need of immediate rehabilitation or renewal. Rehabilitation/repair work likley beyond the capabilities of the pond maintenance crews and will require an engineer. (e.g. badly damaged ponds, access issues, bad original design, major slope/spillway failure, major wet pond dredging, etc.)

Single Phase Pond Configuration

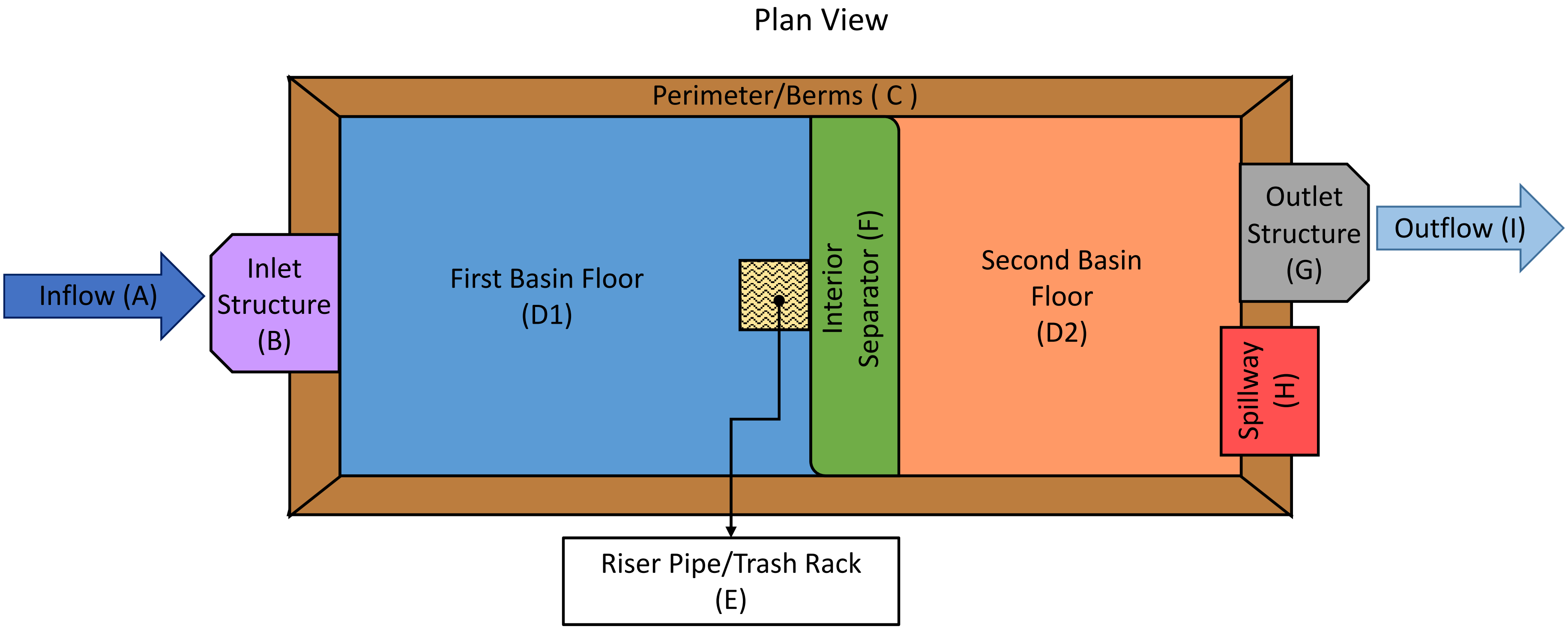
(Detention, Rain Garden, Retention, etc.)

Plan View



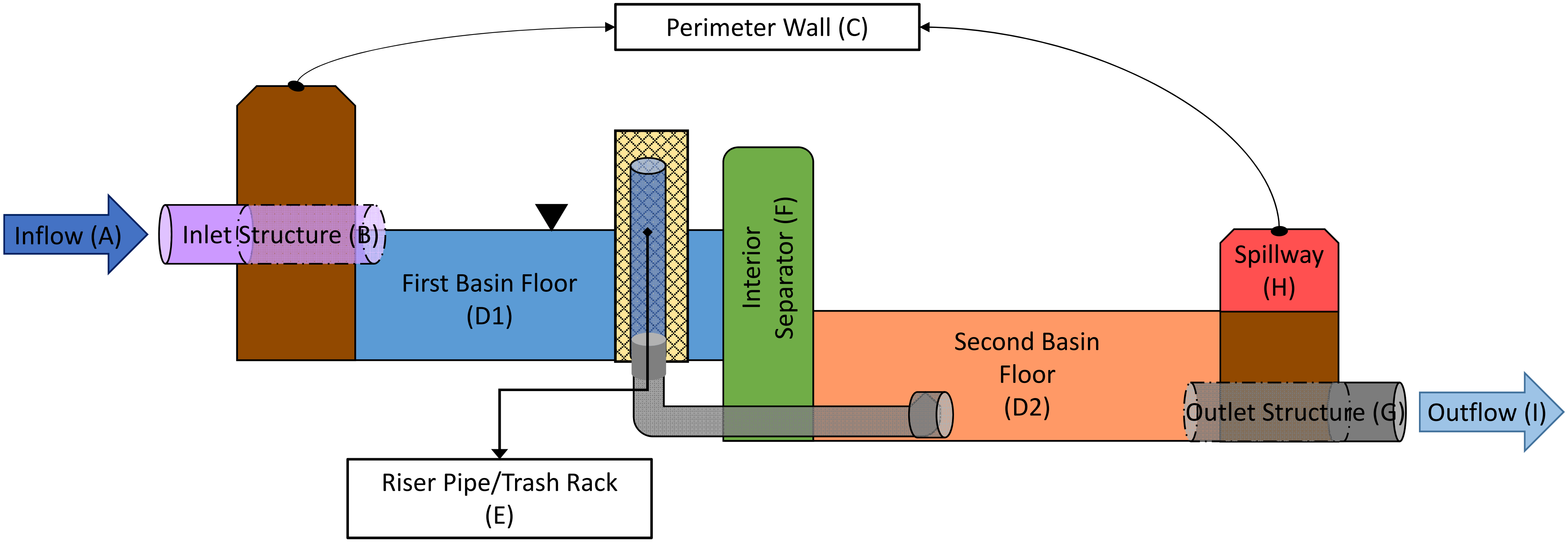
Dual Phase Pond Configuration

(Sedimentation/Filtration)

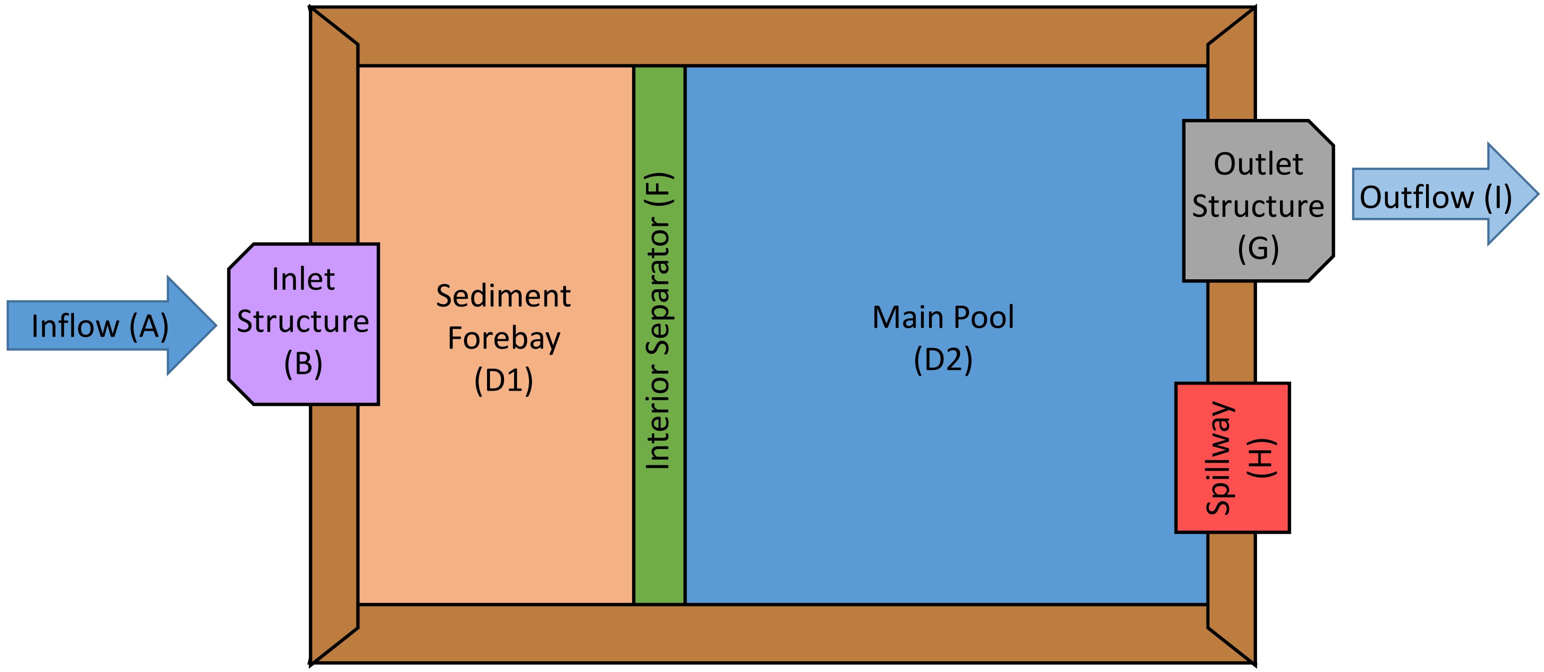


General Dual Phase Pond Configuration

Profile View



Wet Pond Configuration



Appendix B: Potential Risk Area Creation

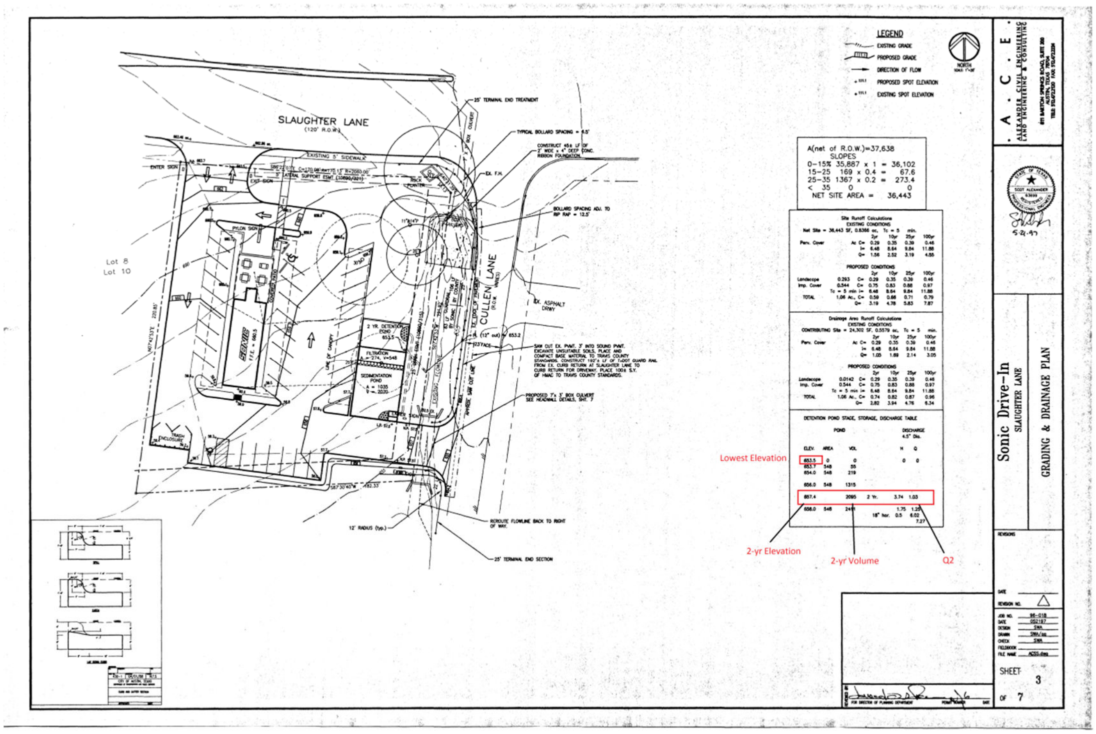
This is the general workflow for establishing Potential Risk Areas for ponds. This would mimic the spread of water should an embankment fail and inundate the surrounding areas. There are two steps, the first is establishing the metrics used to calculate the danger zone and the second is using ArcGIS to perform the analysis to draw the Potential Risk Area polygon.

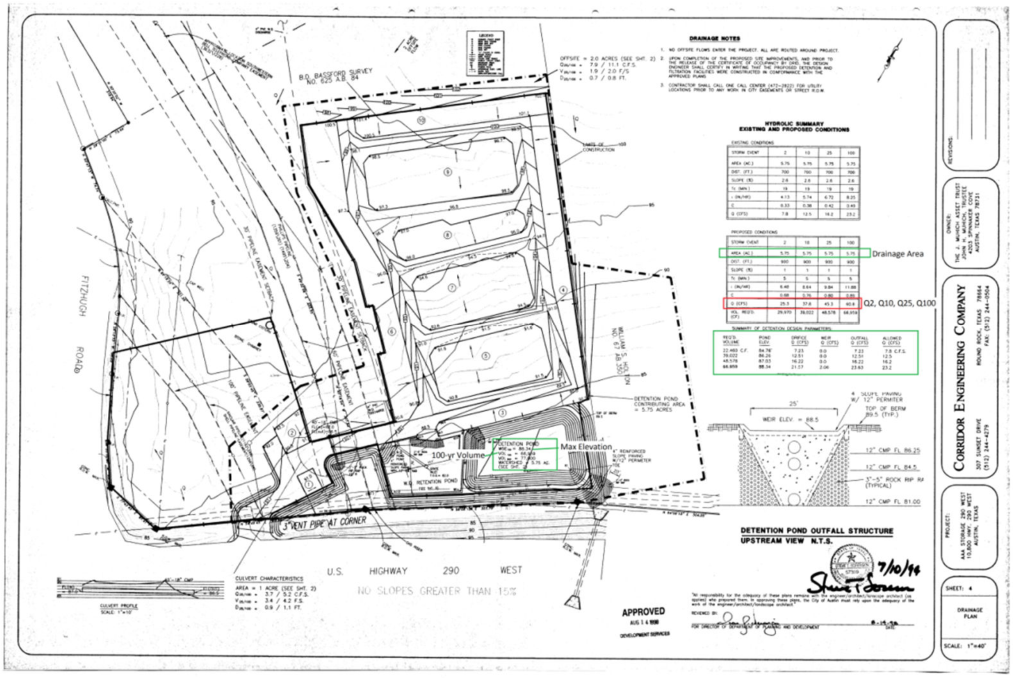
Data

- Simplified Breach length formula: (.012 *([K]*(Sqr (2*([Vol]* ([Depth]+2))))))
- K = constant of 1.8 (determined by the research group when compared to other models)
- Vol = the 100yr detention volume (if available)
- Depth = The 100yr detention depth +2 (determined by the research group when compared to other models)
- Pond data from DIG (UTILITIESCOMMUNICATION.stormwater_control)
- Due to missing data in our GIS database for ponds, volume and depth (100 yr WSE less the pond floor) were located by searching the plan sets for each pond. These are the most typical scenarios that we came across, but there are many different ways the data can be displayed in a planset. If not available from the plan set it was calculated using 3D analyst tools in ArcGIS (see section below in GIS Processing)

Locating Detention Pond Information

- Identify Pond in .mxd
- Get case number/refdoc from the Stormwater Control Layer
- If refdoc is not directly linked to the polygon in the .mxd, copy and paste case number into AMANDA.
- Open plans in AMANDA; go to page titled Drainage Details/Pond Calculations/anything along those lines.
- Go to section titled "Detention Pond Stage, Storage, Discharge Table" (or something similarly titled)
- Record Volume at 100-yr event elevation – or the highest event. (In the example, the detention pond is designed to the 2-yr event)
- Subtract lowest given elevation from elevation of the recorded volume – that is the depth
- Find the flows at the 2-, 10-, 25-, and 100-yr flows; if they are present, write down "TRUE" (or whatever you use to represent flows)

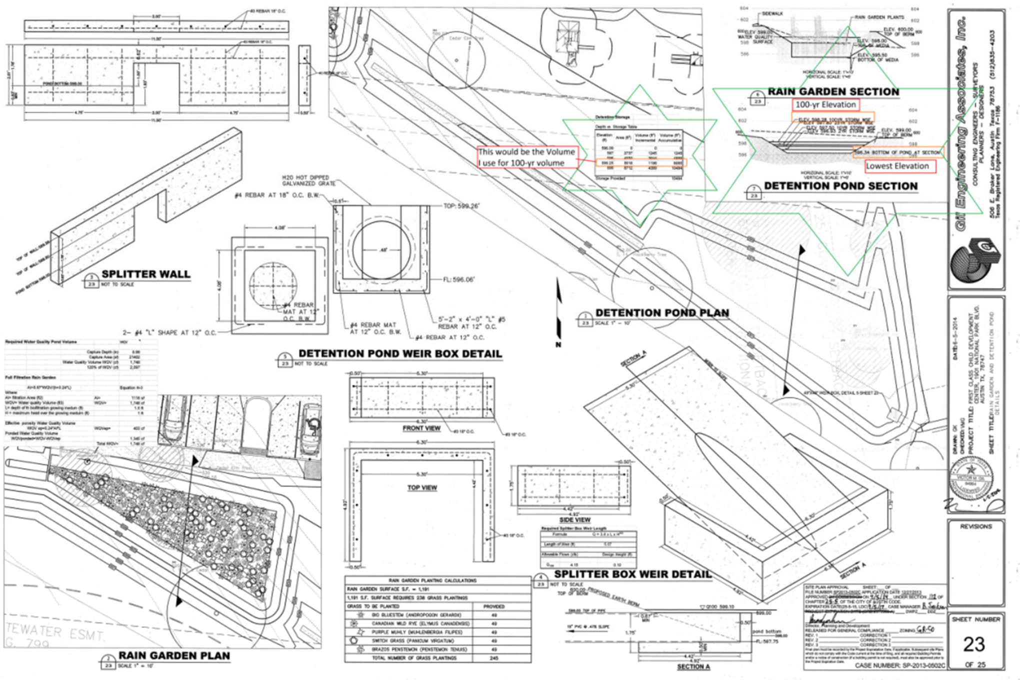




Another Scenario

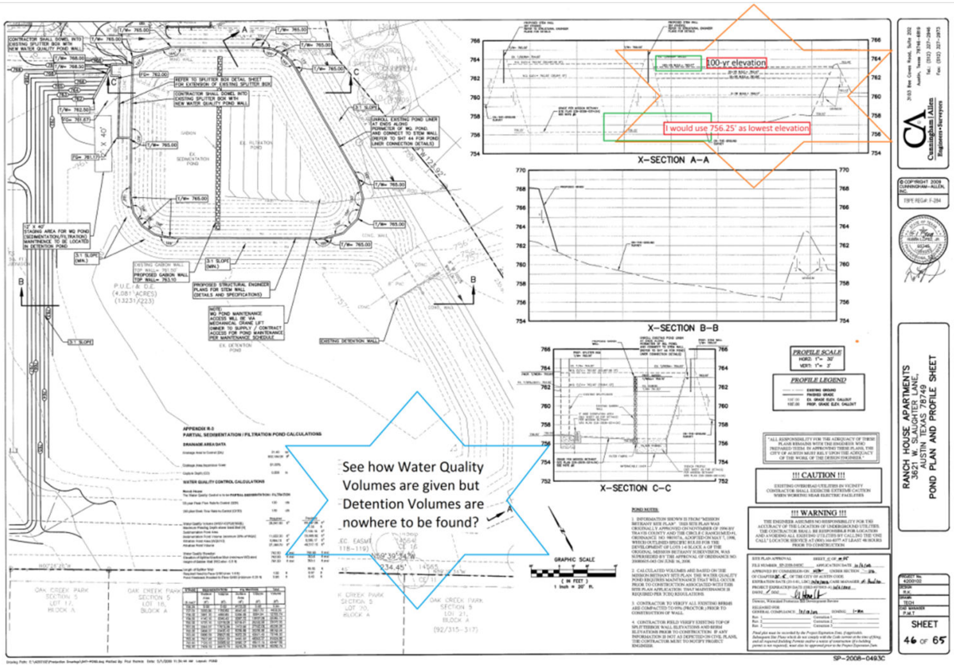
- Sometimes there's a cross-section of the pond in question with the 2-, 10-, 25-, and 100-year elevations; find the 100-yr elevation and elevation at the bottom of the pond, and subtract them to get the depth
- Go to Depth vs. Storage Table. Using the elevations from the cross-section of the pond, DO YOUR BEST to find the appropriate volume for the given elevation (in the example,

they give an elevation that is very close to the 100-yr elevation, but this isn't always the case)



Another Scenario

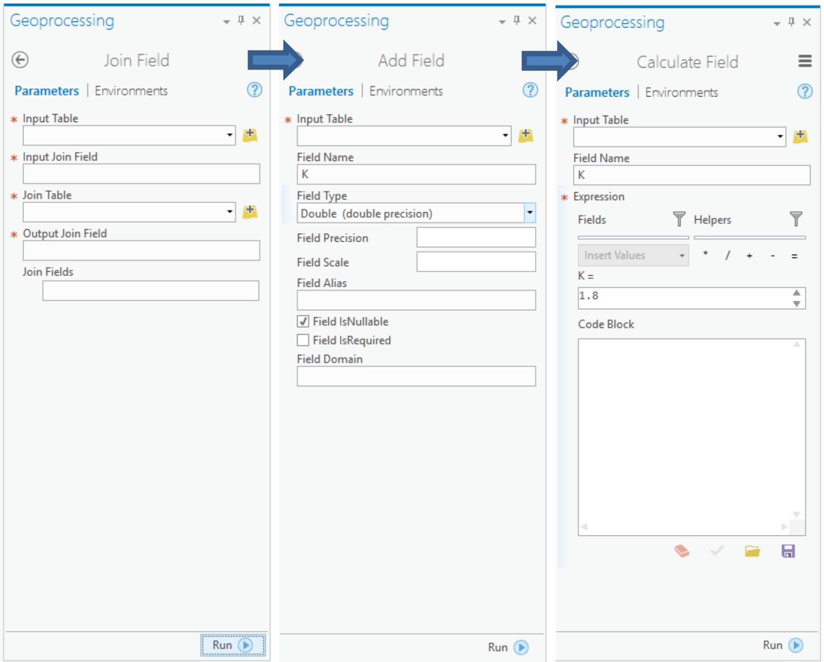
- Sometimes, as hard as you try, you can't find all the info you need, so #DoYourBest
- Find the depth by using the pond cross-section graphic
- I couldn't find any "Depth vs. Volume" table or information, so the only data that would be recorded.



GIS Processing

Potential Risk Area

1. Join the Ponds polygon layer ("Res Ponds"), these are city owned and maintained flood detention ponds, with the table with pond information found on plans (this will become part of the pond geodatabase in FY2018).
2. Add and calculate fields: Z min, Z max, K (a constant of 1,8), Depth, and Z Flood (Depth plus 2 feet as determined by this group).



Field Name: K

Field Type: Double (double precision)

☑ Field IsNullable

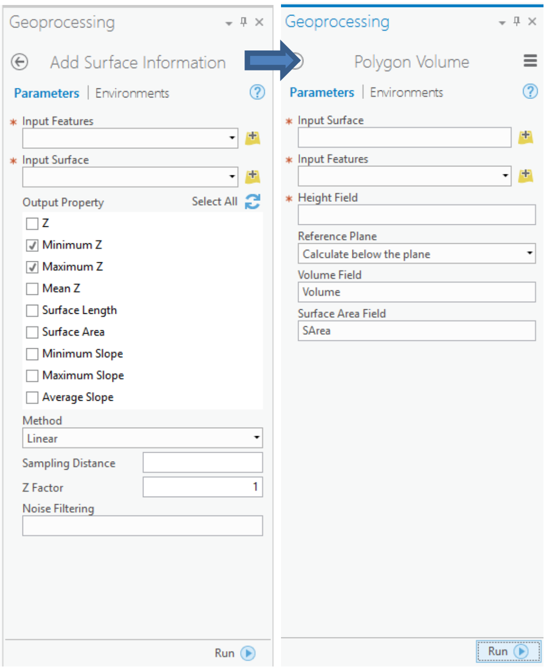
☐ Field IsRequired

Field Name: K

K =

1.8

3. Where the data for these already exists in the pond dataset use that data. Where any are missing go with the data from the table. Where that is still lacking, use the process below to calculate depth and volume.
   A. Add Surface Information (http://pro.arcgis.com/en/pro-app/tool-reference/3d-analyst/add-surface-information.htm). This gives a Z max and a Z min within a polygon (and others if so desired) based on the DEM. The difference between these gives an approximate depth.
   B. Polygon Volume Tool (http://pro.arcgis.com/en/pro-app/tool-reference/3d-analyst/polygon-volume.htm). This uses the Z max calc to calculate the volume under the reference plane (the pond polygon) and the surface (DEM).



Geoprocessing

Add Surface Information

Parameters | Environments

* Input Features

* Input Surface

Output Property — Select All

☐ Z
☑ Minimum Z
☑ Maximum Z
☐ Mean Z
☐ Surface Length
☐ Surface Area
☐ Minimum Slope
☐ Maximum Slope
☐ Average Slope

Method: Linear

Sampling Distance

Z Factor: 1

Noise Filtering

Run

Geoprocessing

Polygon Volume

Parameters | Environments

* Input Surface

* Input Features

* Height Field

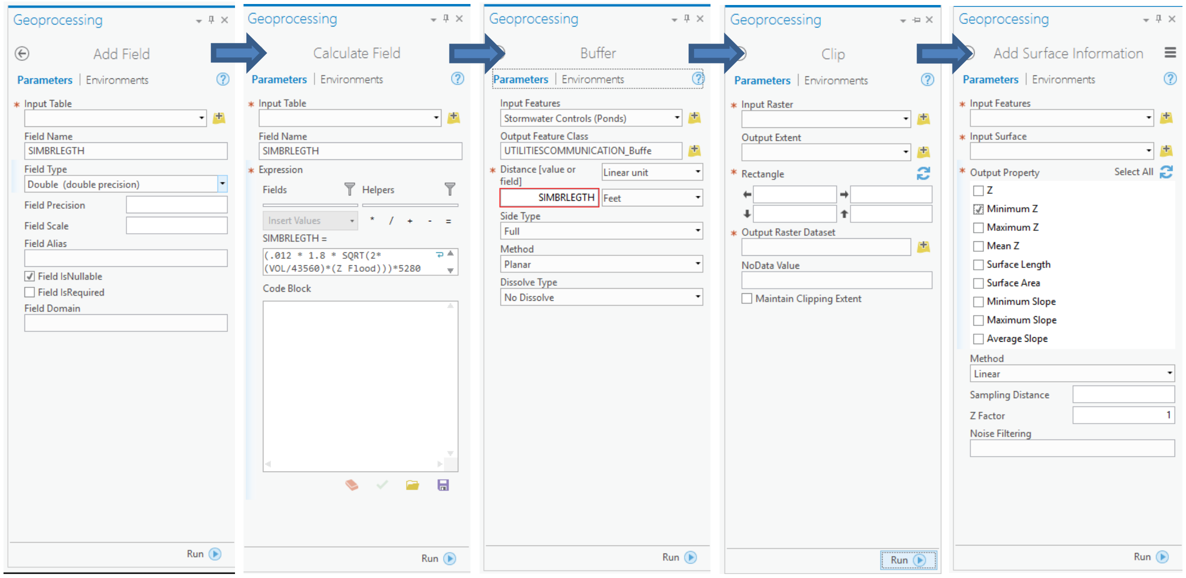
Reference Plane: Calculate below the plane

Volume Field: Volume

Surface Area Field: SArea

Run

4. Add a field for the Simplified Breach Length (Double) “SIMBRLEGTH”
5. Calculate SIMBRLEGTH field (.012 * 1.8 * SQRT(2*(VOL/43560)*(Z Flood)))*5280
6. Buffer the pond using the breach length calculation.
7. Clip DEM to buffers.
8. Add Z values to the buffer with lowest Z in DEM clip



Geoprocessing

Add Field

Parameters | Environments

* Input Table

Field Name: SIMBRLEGTH

Field Type: Double (double precision)

Field Precision

Field Scale

Field Alias

☑ Field IsNullable
☐ Field IsRequired

Field Domain

Run

Geoprocessing

Calculate Field

Parameters | Environments

* Input Table

Field Name: SIMBRLEGTH

* Expression

Fields — Helpers

Insert Values * / + - =

SIMBRLEGTH =

```
(.012 * 1.8 * SQRT(2*
(VOL/43560)*(Z Flood)))*5280
```

Code Block

Run

Geoprocessing

Buffer

Parameters | Environments

Input Features: Stormwater Controls (Ponds)

Output Feature Class: UTILITIESCOMMUNICATION_Buffe

* Distance [value or field]: Linear unit

SIMBRLEGTH — Feet

Side Type: Full

Method: Planar

Dissolve Type: No Dissolve

Run

Geoprocessing

Clip

Parameters | Environments

* Input Raster

Output Extent

* Rectangle

* Output Raster Dataset

NoData Value

☐ Maintain Clipping Extent

Run

Geoprocessing

Add Surface Information

Parameters | Environments

* Input Features

* Input Surface

* Output Property — Select All

☐ Z
☑ Minimum Z
☐ Maximum Z
☐ Mean Z
☐ Surface Length
☐ Surface Area
☐ Minimum Slope
☐ Maximum Slope
☐ Average Slope

Method: Linear

Sampling Distance

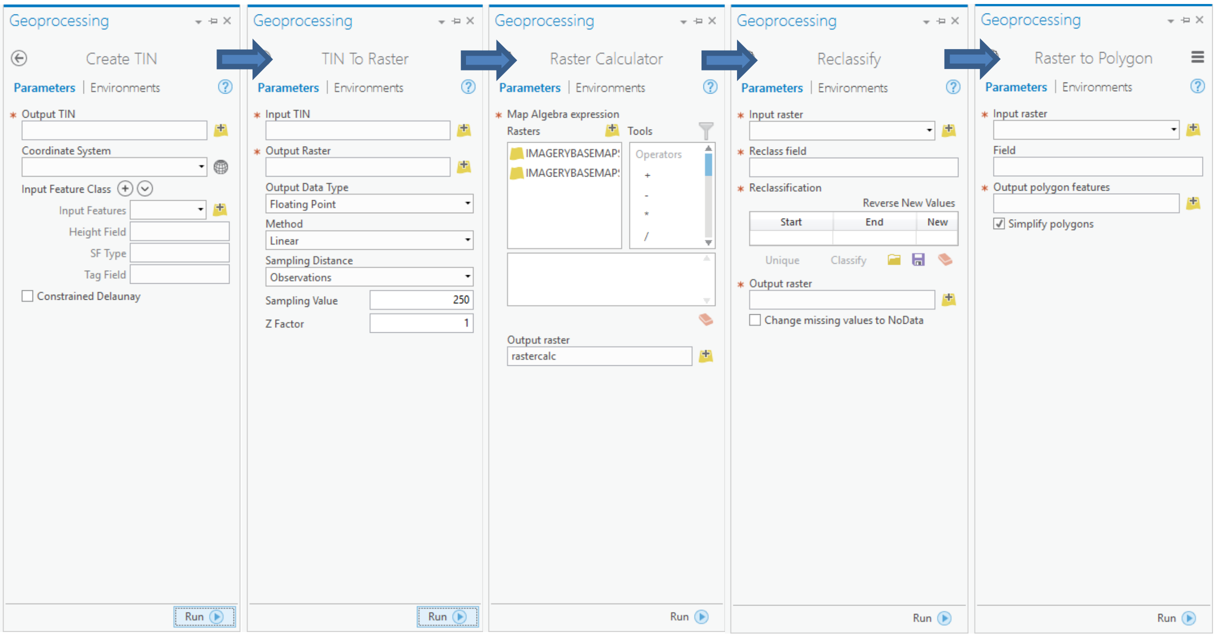
Z Factor: 1

Noise Filtering

Run

9. Create TIN using Pond (Z flood which is equal to Depth plus 2 feet) and Buffer (Z Value, lowest point)
10. Convert TIN to Raster
11. Raster Calculator subtracting Raster from above from the DEM Clip

12. Reclassify the Raster Calculator output to get a 1 for those values that are above ground and a 0 for all other values
13. Convert the Reclassified Raster into a polygon.

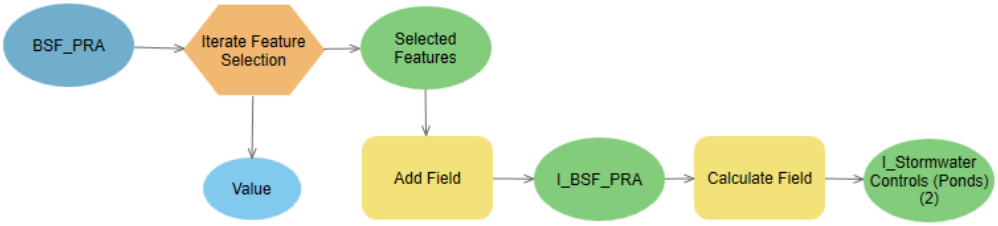


Output Data Type: Floating Point
Method: Linear
Sampling Distance: Observations
Sampling Value: 250
Z Factor: 1

Rasters: IMAGERYBASEMAP! IMAGERYBASEMAP!
Output raster: rastercalc

☑ Simplify polygons

14. Note: if this is done on more than one Pond, best to use an Iterator in ModelBuilder and preserve the Drainage_ID (Value) throughout in the Name Field for each output, using the wildcard %Value%.
15. Add a field and calculate it to attach Drainage ID to the polygon, to relate the pond to the Potential Risk Area. See an example below:



Selection of features in the Potential Risk Area:

1. Perform a spatial join with pond breach polygons as the Target Feature and the street segment layer as the Join Feature. This will be "pond breach polygons join 1."
2. Perform a second spatial join with "pond breach polygons join 1" as the Target Feature and the building footprints layer as the Join Feature. This will be "pond breach polygons join 2."
3. Export "pond breach polygons join 2" to Excel.

4. The attribute “Join_Count” will be the number of street segments that intersect with the pond breach polygon and “Join_Count_1” will be the number of building footprints that intersect with the pond breach polygons.
5. Perform spatial join with street segments layer as the Target Feature and the pond breach polygons as the Join Feature. This will be “street segments join.”
   a. This will give you the specific street segments that intersect with the pond breach polygons along with the Drainage ID that corresponds with the pond breach polygons it intersects with.
6. Export “street segments join” to Excel.