Downstream Assessments in the iSWM Criteria Manual

- = Not typically used or able to meet design criterion.
[1] = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data, if used as a primary control. Third-party sources could include Technology Acceptance Reciprocity Partnership, Technology Assessment Protocol – Ecology, or others.
[2] = Porous surfaces provide water quality benefits by reducing the effective impervious area.

3.2.4 Option 3: Assist with Off-Site Pollution Prevention Programs and Activities

Some communities have implemented pollution prevention programs/activities in certain areas to remove pollutants from the runoff after it has been discharged from the site. This may be especially true in intensely urbanized areas facing site redevelopment where many of the BMP criteria would be difficult to apply. These programs will be identified in the local jurisdiction's approved TPDES stormwater permit and/or in a municipality's approved watershed plan. In lieu of on-site treatment, the developer can request to simply assist with the implementation of these off-site pollution prevention programs/activities.

Developers should contact the municipality to determine if there are any plans to address runoff pollutants within the region of proposed development. If no plans exist, consider proposing regional alternatives that would address pollution prevention.

Local Provisions:

3.3 Acceptable Downstream Conditions

As part of the iSWM Plan development, the downstream impacts of development must be carefully evaluated for the two focus areas of Streambank Protection and Flood Mitigation. The purpose of the downstream assessment is to protect downstream properties from increased flooding and downstream channels from increased erosion potential due to upstream development. The importance of the downstream assessment is particularly evident for larger sites or developments that have the potential to dramatically impact downstream areas. The cumulative effect of smaller sites, however, can be just as dramatic and, as such, following the *integrated* Focus Areas is just as important for the smaller sites as it is for the larger sites.

The assessment shall extend from the outfall of a proposed development to a point downstream where the discharge from a proposed development no longer has a significant impact, in terms of flooding increase or velocity above allowable, on the receiving stream or storm drainage system. The local jurisdiction shall be consulted to obtain records and maps related to the National Flood Insurance Program and the availability of Flood Insurance Studies and Flood Insurance Rate Maps (FIRMs) which will be helpful in this assessment. The assessment shall be a part of the preliminary and final iSWM plans, and must include the following properties:

- Hydrologic analysis of the pre- and post-development on-site conditions
- Drainage path that defines extent of the analysis
- Capacity analysis of all existing constraint points along the drainage path, such as existing floodplain developments, underground storm drainage systems culverts, bridges, tributary confluences, or channels
- Offsite undeveloped areas are considered as "full build-out" for both the pre- and post-development analyses
- Evaluation of peak discharges and velocities for three 24-hour storm events
    - Streambank protection storm
    - Conveyance storm
    - Flood mitigation storm

- Separate analysis for each major outfall from the proposed development

Once the analysis is complete, the designer must answer the following three questions at each determined junction downstream:

- Are the post-development discharges greater than the pre-development discharges?
- Are the post-development velocities greater than the pre-development velocities?
- Are the post-development velocities greater than the velocities allowed for the receiving system?
- Are the post-development flood heights more than 0.1 feet above the pre-development flood heights?

These questions shall be answered for each of the three storm events. The answers to these questions will determine the necessity, type, and size of non-structural and structural controls to be placed on-site or downstream of the proposed development.

Section 2.0 of the Hydrology Technical Manual gives additional guidance on calculating the discharges and velocities, as well as determining the downstream extent of the assessment.

Local Provisions:

3.4 Streambank Protection

The second focus area is in streambank protection. There are three options by which a developer can provide adequate streambank protection downstream of a proposed development. The first step is to perform the required downstream assessment as described in Section 3.3. If it is determined that the proposed project does not exceed acceptable downstream velocities or the downstream conditions are improved to adequately handle the increased velocity, then no additional streambank protection is required. If on-site or downstream improvements are required for streambank protection, easements or right-of-entry agreements will need to be obtained in accordance with Section 3.7. If the downstream assessment shows that the velocities are within acceptable limits, then no streambank protection is required. Acceptable limits for velocity control are contained in Tables 3.10 and 3.11.

Option 1: Reinforce/Stabilize Downstream Conditions

If the increased velocities are greater than the allowable velocity of the downstream receiving system, then the developer must reinforce/stabilize the downstream conveyance system. The proposed modifications must be designed so that the downstream system is protected from the post-development velocities. The developer must provide supporting calculations and/or documentation that the downstream velocities do not exceed the allowable range once the downstream modifications are installed.

Allowable bank protection methods include stone riprap, gabions, and bio-engineered methods. *Sections 3.2 and 4.0 of the Hydraulics Technical Manual* give design guidance for designing stone riprap for open channels, culvert outfall protection, riprap aprons for erosion protection at outfalls, and riprap basins for energy dissipation.

Local Provisions:

Option 2: Install Stormwater Controls to Maintain Existing Downstream Conditions

The developer must use on-site controls to keep downstream post-development discharges at or below allowable velocity limits. The developer must provide supporting calculations and/or documentation that the on-site controls will be designed such that downstream velocities for the three storm events (Streambank Protection, Conveyance, and Flood Mitigation) are within an allowable range once the controls are installed.

Local Provisions:

Option 3: Control the Release of the 1-yr, 24-hour Storm Event

Twenty-four hours of extended detention shall be provided for on-site, post-developed runoff generated by the 1-year, 24-hour rainfall event to protect downstream channels. The required volume for extended detention is referred to as the Streambank Protection Volume (denoted SP_v). The reduction in the frequency and duration of bankfull flows through the controlled release provided by extended detention of the SP_v will reduce the bank scour rate and severity.

To determine the SP_v refer to *Section 3.0 of the Hydrology Technical Manual*.

Local Provisions:

3.5 Flood Mitigation

3.5.1 Introduction

Flood analysis is based on the design storm events as defined in Section 1.3: for conveyance storm and the flood mitigation storm.

The intent of the flood mitigation criteria is to provide for public safety; minimize on-site and downstream flood impacts from the three storm events; maintain the boundaries of the mapped 100-year floodplain; and protect the physical integrity of the on-site stormwater controls and the downstream stormwater and flood mitigation facilities.

Flood mitigation must be provided for on-site conveyance system, as well as downstream outfalls as described in the following sections.

3.5.2 Flood Mitigation Design Options

There are three options by which a developer may address downstream flood mitigation. These options closely follow the three options for Streambank Protection. When on-site or downstream modifications are required for downstream flood mitigation, easements or right-of-entry agreements will need to be obtained in accordance with Section 3.7.

The developer will provide all supporting calculations and/or documentation to show that the existing downstream conveyance system has capacity (Q_f) to safely pass the full build-out flood mitigation storm discharge.

Option 1: Provide Adequate Downstream Conveyance Systems

When the downstream receiving system does not have adequate capacity, then the developer shall provide modifications to the off-site, downstream conveyance system. If this option is chosen the proposed modifications must be designed to adequately convey the full build-out stormwater peak discharges for the three storm events. The modifications must also extend to the point at which the discharge from the proposed development no longer has a significant impact on the receiving stream or storm drainage system. The developer must provide supporting calculations and/or documentation that the downstream peak discharges and water surface elevations are safely conveyed by the proposed system, without endangering downstream properties, structures, bridges, roadways, or other facilities.

Option 2: Install Stormwater Controls to Maintain Existing Downstream Conditions

When the downstream receiving system does not have adequate capacity, then the developer shall provide stormwater controls to reduce downstream flood impacts. These controls include on-site controls such as detention, regional controls, and, as a last resort, local flood protection such as levees, floodwalls, floodproofing, etc.

The developer must provide supporting calculations and/or documentation that the controls will be designed and constructed so that there is no increase in downstream peak discharges or water surface elevations due to development.

Option 3: In lieu of a Downstream Assessment, Maintain Existing On-Site Runoff Conditions

Lastly with Option 3, on-site controls shall be used to maintain the pre-development peak discharges from the site. The developer must provide supporting calculations and/or documentation that the on-site controls will be designed and constructed to maintain on-site existing conditions.

It is important to note that Option 3 does not require a downstream assessment. It is a detention-based approach to addressing downstream flood mitigation after the application of the *integrated* site design practices.

For many developments however, the results of a downstream assessment may show that significantly less flood mitigation is required than "detaining to pre-development conditions". This method may also exacerbate downstream flooding problems due to timing of flows. The developer shall confirm that detention does not exacerbate peak flows in downstream reaches.

3.6 Stormwater Conveyance Systems

3.6.1 Introduction

Stormwater system design is an integral component of both site and overall stormwater management design. Good drainage design must strive to maintain compatibility and minimize interference with existing drainage patterns; control flooding of property, structures, and roadways for design flood events; and minimize potential environmental impacts on stormwater runoff.

Stormwater collection systems must be designed to provide adequate surface drainage while at the same time meeting other stormwater management goals such as water quality, streambank protection, habitat protection, and flood mitigation.

Design

Fully developed watershed conditions shall be used for determining runoff for the conveyance storm and the flood mitigation storm.

Local Provisions:

3.6.2 Hydraulic Design Criteria for Streets and Closed Conduits

Introduction

This section is intended to provide criteria and guidance for the design of on-site flood mitigation system components including:

- Street and roadway gutters
- Stormwater inlets
- Parking lot sheet flow
- Storm drain pipe systems

Streets and Stormwater Inlets

<u>Design Frequency</u>

- Streets and roadway gutters: conveyance storm event
- Inlets on-grade: conveyance storm event
- Parking lots: conveyance storm event
- Storm drain pipe systems: conveyance storm event
- Low points: flood mitigation storm event
- Street ROW: flood mitigation storm event
- Drainage and Floodplain easements: flood mitigation storm event

Downstream Assessments in the iSWM Hydrology Technical Manual

2.0 Downstream Assessment

2.1 Introduction

The downstream impacts of development must be carefully evaluated. The purpose of the downstream assessment is to protect downstream properties from increased flooding and downstream channels from increased erosion potential due to upstream development. The importance of the downstream assessment is particularly evident for larger sites or developments that have the potential to dramatically impact downstream areas. The cumulative effect of smaller sites, however, can be just as dramatic.

The assessment should extend from the outfall of a proposed development to a point downstream where the discharge from a proposed development no longer has a significant impact on the receiving stream or storm drainage system. The assessment should be a part of the concept, preliminary, and final iSWM plans, and should include the following properties:

- Hydrologic analysis of the pre- and post-development on-site conditions
- Drainage path which defines extent of the analysis.
- Capacity analysis of all existing constraint points along the drainage path, such as existing floodplain developments, underground storm drainage systems culverts, bridges, tributary confluences, or channels
- Offsite undeveloped areas are considered as “full build-out” for both the pre- and post-development analyses
- Evaluation of peak discharges and velocities for three (3) 24-hour storm events
    - “Streambank Protection” storm
    - “Conveyance” storm
    - “Flood Mitigation” storm
- Separate analysis for each major outfall from the proposed development

Once the analysis is complete, the designer should ask the following three questions at each determined junction downstream:

- Are the post-development discharges greater than the pre-development discharges?
- Are the post-development velocities greater than the pre-development velocities?
- Are the post-development velocities greater than the velocities allowed for the receiving system?

These questions should be answered for each of the three storm events. The answers to these questions will determine the necessity, type, and size of non-structural and structural controls to be placed on-site or downstream of the proposed development.

2.2 Downstream Hydrologic Assessment

Common practice requires the designer to control peak flow at the outlet of a site such that post-development peak discharge equals pre-development peak discharge. It has been shown that in certain cases this does not always provide effective water quantity control downstream from the site and may actually exacerbate flooding problems downstream. The reasons for this have to do with (1) the timing of the flow peaks, and (2) the total increase in volume of runoff.

Due to a site’s location within a watershed, there may be very little reason for requiring flood control from a particular site. In certain circumstances where detention is in place or a master drainage plan has been adopted, a development may receive or plan to receive less that ultimate developed flow conditions from upstream. This might be considered in the detention needed and its influence on the downstream assessment. Any consideration in such an event would be with the approval of the local authority. This section outlines a suggested procedure for determining the impacts of post-development stormwater peak flows and volumes that a community may require as part of a developer's stormwater management site plan.

2.3 Reasons for Downstream Problems

Flow Timing

If water quantity control (detention) structures are indiscriminately placed in a watershed and changes to the flow timing are not considered, the structural control may actually increase the peak discharge downstream. The reason for this may be seen in Figure 2.1. The peak flow from the site is reduced appropriately, but the timing of the flow is such that the combined detained peak flow (the larger dashed triangle) is actually higher than if no detention were required.

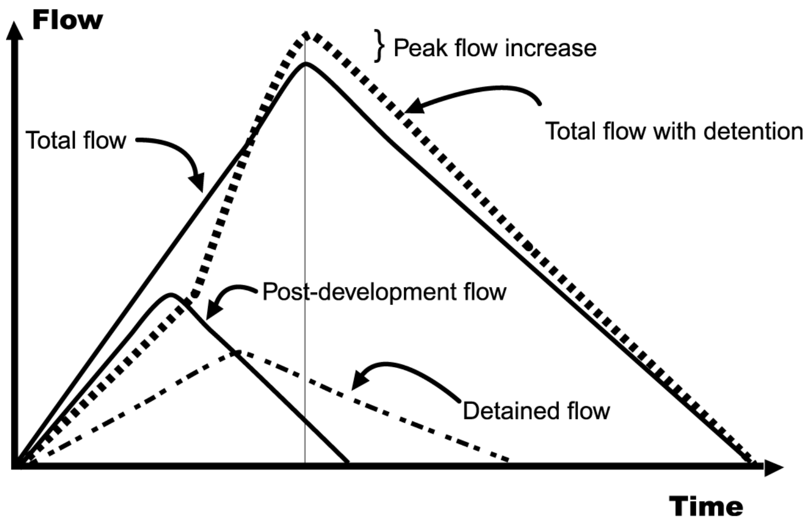

Figure 2.1 Detention Timing Example

In this case, the shifting of flows to a later time brought about by the detention pond actually makes the downstream flooding worse than if the post-development flows were not detained. This is most likely to happen if detention is placed on tributaries towards the bottom of the watershed, holding back peak flows and adding them as the peak from the upper reaches of the watershed arrives.

Increased Volume

An important impact of new development is an increase in the total runoff volume of flow. Thus, even if the peak flow is effectively attenuated, the longer duration of higher flows due to the increased volume may combine with downstream tributaries to increase the downstream peak flows.

Figure 2.2 illustrates this concept. The figure shows the pre- and post-development hydrographs from a development site (Tributary 1). The post-development runoff hydrograph meets the flood protection criteria (i.e., the post-development peak flow is equal to the pre-development peak flow at the outlet from the site). However, the post-development combined flow at the first downstream tributary (Tributary 2) is higher than pre-development combined flow. This is because the increased volume and timing of runoff from the developed site increases the combined flow and flooding downstream. In this case, the detention volume would have to have been increased to account for the downstream timing of the combined hydrographs to mitigate the impact of the increased runoff volume.

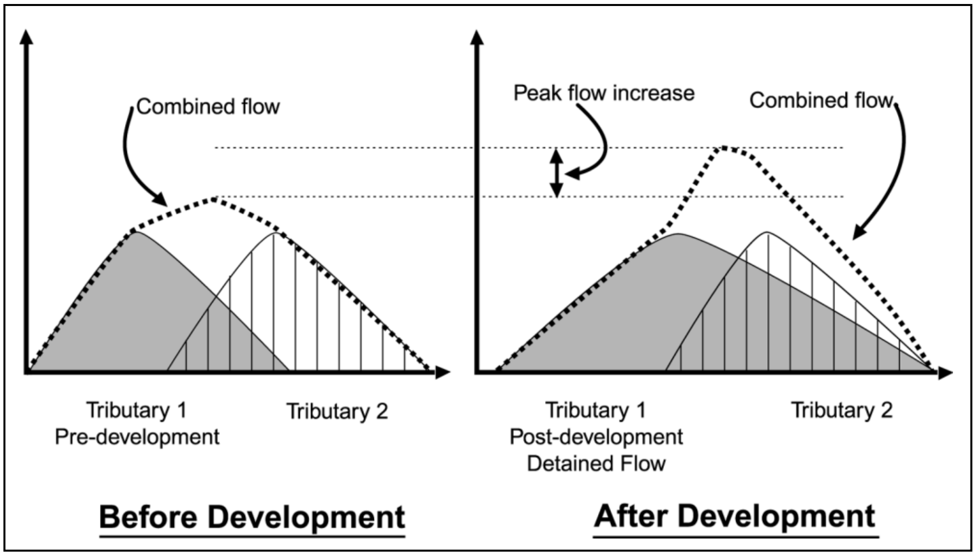

Figure 2.2 Effect of Increased Post-Development Runoff Volume with Detention on a Downstream Hydrograph

2.4 Methods for Downstream Evaluation

The downstream assessment is a tool by which the impacts of development on stormwater peak flows and velocities are evaluated downstream. The assessment extends from an outfall of a development to a point downstream, determined by one of two methods:

- *Zone of Influence* – Point downstream where the discharge from a proposed development no longer has a significant impact upon the receiving stream or storm drainage system
- *Adequate Outfall* – Location of acceptable outfall that does not create adverse flooding or erosion conditions downstream

These methods recognize the fact that a structural control providing detention has a "zone of influence" downstream where its effectiveness can be felt. Beyond this zone of influence the stormwater effects of a structural control become relatively small and insignificant compared to the runoff from the total drainage area at that point. Based on studies and master planning results for a large number of sites, a general rule of thumb is that the zone of influence can be considered to be the point where the drainage area controlled by the detention or storage facility comprises 10% of the total drainage area. This is known as the *10% Rule*. As an example, if a structural control drains 10 acres, the zone of influence ends at the point where the total drainage area is 100 acres or greater.

Typical steps in a downstream assessment include:

4. Determine the outfall location of the site and the pre- and post-development site conditions.

- Using a topographic map determine a preliminary lower limit of the zone of influence (approximately 10% point).
- Using a hydrologic model determine the pre-development peak flows and velocities at each junction beginning at the development outfall and ending at the next junction beyond the 10% point. Undeveloped off-site areas are modeled as "full build-out" for both the pre- and post-development analyses. The discharges and velocities are evaluated for three storms:

    5.

a. “Streambank Protection” storm

b. “Conveyance” storm

c. “Flood Mitigation” storm

- Change the land use on the site to post-development conditions and rerun the model.
- Compare the pre- and post-development peak discharges and velocities at the downstream end of the model. If the post-developed flows are higher than the pre-developed flows for the same frequency event, or the post-developed velocities are higher than the allowable velocity of the downstream receiving system, extend the model downstream. Repeat steps 3 and 4 until the post-development flows are less than the pre-developed flows, and the post-developed velocities are below the allowable velocity. Allowable velocities are given in *Table 3.2 of the Hydraulics Technical Manual.*
- If shown that no peak flow increases occur downstream, and post-developed velocities are allowable, then the control of the flood protection volume (Q_f) can be waived by the local authority. The developer saves the cost of sizing a detention basin for flood control. In this case the downstream assessment saved the construction of an unnecessary structural control facility that would have been detrimental to the watershed flooding problems. In some communities this situation may result in a fee being paid to the local government in lieu of detention. That fee would go toward alleviating downstream flooding or making channel or other conveyance improvements.
- If peak discharges are increased due to development, or if downstream velocities are erosive, one of the following options are required.
  - Document that existing downstream conveyance is adequate to convey post-developed stormwater discharges (Option 1 for Streambank Protection and Flood Control)
  - Work with the local government to reduce the flow elevation and/or velocity through channel or flow conveyance structure improvements downstream. (Option 2 for Streambank Protection and Flood Control)
  - Design an on-site structural control facility such that the post-development flows do not increase the peak flows, and the velocities are not erosive, at the outlet and the determined junction locations.

Even if the results of the downstream assessment indicate that no downstream flood or erosion protection is required, the water quality steps of the *integrated* Design Approach will still need to be addressed.

2.5 Example Problem

Figure 2.3 illustrates the concept of the ten-percent rule for two sites in a watershed.

Discussion
Site A is a development of 10 acres, all draining to a wet Extended Detention (ED) stormwater pond. The flood portions of the design are going to incorporate the ten-percent rule. Looking downstream at each tributary in turn, it is determined that the analysis should end at the tributary marked “80 acres.” The 100-acre (10%) point is in between the 80-acre and 120-acre tributary junction points.

The assumption is that if there is no peak flow increase or erosive velocities at the 80-acre point then the same will be true through the next stream reach downstream through the 10% point (100 acres) to the 120-acre point. The designer constructs a simple HEC-1 model of the 80-acre areas using single, “full build-out” condition sub-watersheds for each tributary. Key detention structures existing in other tributaries must be modeled. An approximate curve number is used since the *actual* peak flow is not key for initial analysis; only the increase or decrease is important. The accuracy in curve number determination is not as significant as an accurate estimate of the time of concentration. Since flooding is an issue downstream, the pond is designed (through several iterations) until the peak flow does not increase, and velocities are not erosive, at junction points downstream to the 80-acre point.

Site B is located downstream at the point where the total drainage area is 190 acres. The site itself is only 6 acres. The first tributary junction downstream from the 10% point is the junction of the site outlet with the stream. The total 190 acres is modeled as one basin with care taken to estimate the time of concentration for input into the TR-20 model of the watershed. The model shows a detention facility, in this case, will actually increase the peak flow in the stream.

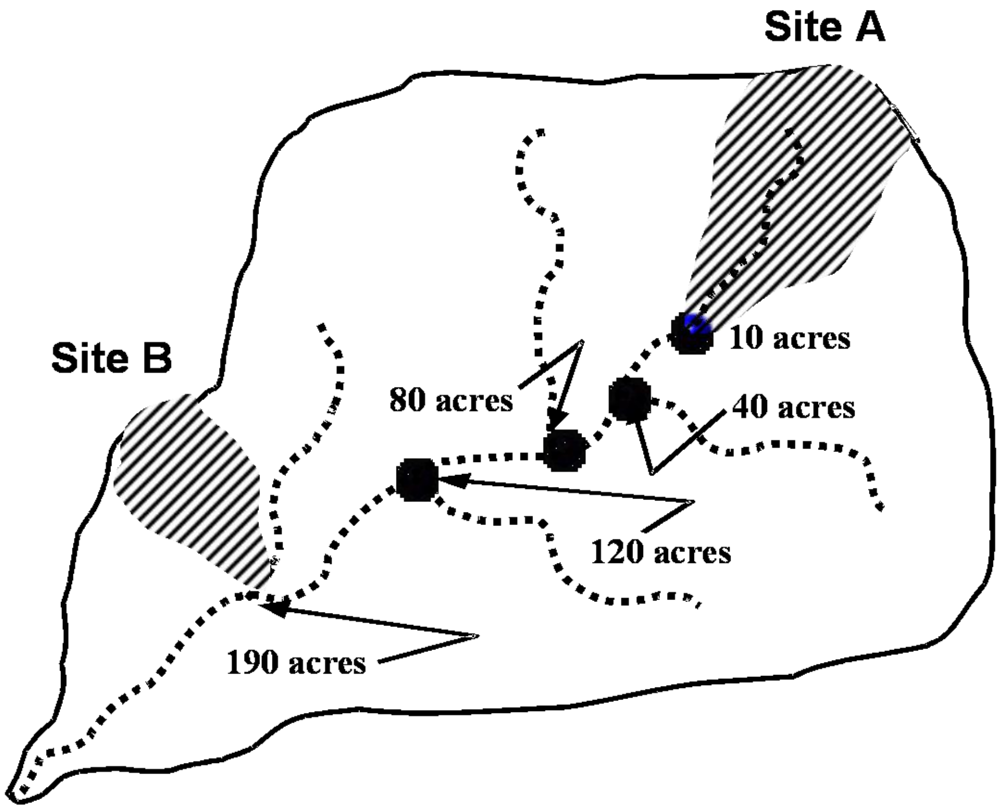

Figure 2.3 Example of the Ten-Percent Rule