Title: Quantifying the Effects of Highway Construction on the Peak Rate and Volume of Storm Water Runoff in Rural and Moderately Urbanized Watersheds.

State Job Number: 14753  
PID Number:  
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Study Start Date: June 6, 2000  
Study Completion Date: July 31, 2003  
Study Duration: 38 months  
Study Cost: $120,850  
Study Funding Type: 80 Federal / 20 State

STATEMENT OF NEED:
The Ohio EPA was contemplating if ODOT should retain storm water. ODOT requested that a researcher study the effects of linear highway construction on previously undeveloped land. The effects of highway construction on rural to moderately urbanized watersheds is not well documented. At some level of highway construction, impacts can be expected. Currently, the normal highway drainage design does not consider the highway runoff effects on the watershed.

RESEARCH OBJECTIVES:
Quantify the effects of pre and post highway construction on the natural drainage.

RESEARCH TASKS:
- Identify two watershed sites with historical stream and rain gage information.
- Develop and calibrate a computer model of those sites in an attempt to replicate how the drainage reacts to linear highway development.
- Determine the impact level of highway construction.
- Attempt to generalize the results for other Ohio watersheds.
- Provide documented results and report their findings.

RESEARCH DELIVERABLES:
The Final Report summarizing their findings.
RESEARCH RECOMMENDATIONS:

- The research showed that linear transportation systems do indeed create increased runoffs. The effects of highway construction on the peak rate and volume of storm water runoff from a watershed can be accurately determined for existing and proposed highways.

- The storm water runoff from a natural watershed can be accurately simulated, and that the effect of a future highway on the response of the watershed can be predicted.

- Storm water management should become a standard procedure for all highway construction undertaken or funded by the Ohio Department of Transportation.

- The effect of highway construction on the watershed should be evaluated for both proposed highways and existing highways.

- Recommendations are provided in this report to permit incorporating storm water management into the ODOT Location and Design Manual.

- The modeling of the hypothetical watersheds, developed as a component of this project, could be used with modification to determine the return periods of the critical storm for all of the standard highway types shown in the ODOT Location and Design Manual. Design charts could then be developed and incorporated into the Location and Design Manual.

PROJECT PANEL COMMENTS:

William J. Krouse:
Stream and water quality should benefit from the new OHIO EPA requirements. The research showed us that linear transportation systems do increase the runoff rates, which thereby erode the natural banks of downstream channels and destroy habitat. Ohio EPA changed the methodology of their Storm Water Management Plan, therefore the Critical Storm Methods used by this Researcher was abandoned. Volume 2 of the L&D Manual was revised to comply with the revised OEPA regulations.

Omar Abu-Hajar:
Even though the method used in this research was not recommended by the Ohio EPA in their final regulations for storm water management, it confirmed the need to better manage out-flow quantity and quality of projects constructed by ODOT. Roadway widening or constructing a new highway will cause flow rates to increase due to increased impervious areas for asphalt and side-slopes. The consequences of implementing the research recommendations along with the Ohio EPA regulations is to have better water quality downstream form the newly constructed highway. Also, outflow rate reduction will reduce flood risks and erosion in Ohio’s waterways.

IMPLEMENTATION STEPS & TIME FRAME:
The Ohio EPA drafted storm water management guidelines. This first draft was published prior to the completion of this research. The Ohio EPA’s draft storm water regulations required that the Critical Storm Method be used as the design methodology when determining how much storm water to retain. The Critical Storm Method is based on determining how much increase in volume of runoff that the development created. Many of the research conclusions in the report are based on the Critical Storm Method. Based on comments from practitioners, the Ohio EPA took an entirely different approach to storm water management. Since this research is fairly narrowly focused on the Critical Storm Method which was subsequently abandoned by the Ohio EPA, it lacks many directly implementable conclusions. This research does not apply to the final construction permit as now issued by the Ohio EPA. The new OEPA approach essentially requires that developers to store a prescribed volume of water known as the Water Quality Volume. Since the Ohio EPA now mandates water quality volume, ODOT has
implemented into Volume 2 of the L&D Manual new requirements to ensure compliance. See Attachment of Section 1115 of this manual.

EXPECTED BENEFITS:
We benefited from the knowledge that linear highway construction can influence the volume of runoff in a drainage basin.

EXPECTED RISKS, OBSTACLES, & STRATEGIES TO OVERCOME THEM:
ODOT has already adopted the new regulations as shown in the attachment. Right of way limitations and other construction restrictions may cause some risks, but proper planning and funding will overcome these risks.

OTHER ODOT OFFICES AFFECTED BY THE CHANGE:
Design, plan preparation, and construction have been affected by the new requirements. Consequently, Production, Construction, and District Offices are the most affected by the change.

PROGRESS REPORTING & TIME FRAME:
This research has already been implemented, so no need for progress reporting.

TECHNOLOGY TRANSFER METHODS TO BE USED:
Quality Assurance Reviews (QAR's) are in progress to introduce the Districts to the new requirements. A number of workshops have been held on the subject by Office of Structural Engineering, Hydraulics Section. The Hydraulics web site has provided information since the revision of the Drainage Manual on the subject. The Office of Research and Development will be providing copies of the Final report of the research along with posting it on the R&D web site.

IMPLEMENTATION COST & SOURCE OF FUNDING:
The labor cost to revise the Drainage Manual funded by office overhead. Complying with the new requirements will increase construction costs funded by ODOT Districts.

Approved By: (attached additional sheets if necessary)
Office Administrator(s):
Signature: Tim Keller Office: OSE Date: 11/03/04
Signature: ______________________ Office: ______ Date: __________

Division Deputy Director(s):
Signature: Tony Alysh Division: Hwy Ops Date: 11/28/14
Signature: ______________________ Division: ______ Date: ________
1115 Post Construction Storm Water Management

1115.1 Threshold limits
Post construction storm water management controls shall be used for all projects that meet any one of the following threshold limits:

- Impervious surface (total cross section) width is 60 feet or greater.
- ADT is greater than 30,000 and roadway is classified as rural.
- More than 80 percent of the drained area is discharged through a closed storm sewer system.
- Project is located within an ODOT MS4 Phase II regulated area.
- Storm water outfall is into a TMDL regulated stream where highway runoff has been identified as a regulated pollutant source.

For projects not meeting the above criteria, measures shall be taken to provide maximum vegetation and retention time through the use of ditches and swales. Current research has indicated that typical roadway design using vegetated slopes and ditches will provide the appropriate storm water treatment for these projects.

1115.2 General
The following requirements pertain to projects that meet or exceed limits as stated in section 1115.1:

Projects that range from 1 to 5 acres shall use measures to control the pollutants in the storm water discharge (ie: quality). Specific detention times are not required for projects within this range. Typical roadway design that uses vegetated side slopes and ditches fulfill this requirement. In highly urbanized areas, consideration may be given to installing sumps in catch basins or using manufactured systems.

Projects that disturb 5 or more acres must provide measures to treat the quality and quantity of storm water (if feasible). These measures are accomplished by providing treatment for the water quality volume, water quality flow, or a combination of both. Specific detention times or velocities are required to be met to fulfill the quantity aspect of the requirements.

Rehabilitation projects that disturb 5 acres or more shall be designed to either ensure a 20 % net reduction of impervious area (asphalt or concrete), or provide treatment for 20 % of the total water quality volume from the combined existing and proposed area draining to each outfall.

Exceptions to this requirement may be granted if it can be shown that the existing runoff hydrograph matches the proposed runoff hydrograph through a hydrologic study. Exceptions shall be submitted to the Office of Structural Engineering, Hydraulics Section.

Placement and protection of Structural Best Management Practices shall be in accordance with Location and Design, Volume I.

Every effort should be made to separate off site drainage from the roadway drainage when possible. This will reduce the acreage amount to be treated by the post construction storm water management systems.

1115.3 Water Quality Volume (WQv)
The water quality volume captures the "maximized" water quantity which then protects receiving bodies for water quality and quantity. The volume is increased by 20% to allow for sediment deposition and ineffective storage (reflected by the "1.2" in the equation). Further increase of the volume does not provide significant pollution removal efficiency. The following equation shall be used to calculate the water quality volume:

\[ WQv = \frac{(1.2\times P \times Cq \times A)}{12} \]

Where,

- \( P \) = Precipitation (0.75 inches)
- \( A \) = Acres (drainage area)
- \( WQv \) = Water Quality Volume (acre-ft)
- \( Cq = 0.858i^2 - 0.78i^2 + 0.774i + 0.04 \)

Where, \( i \) = Impervious Ratio (percent total imperviousness divided by 100) (decimal)
Drainage Design Procedures

1115.3.1 Offsite Drainage Area

Contributing offsite drainage area should be separated from ODOT's roadway drainage area when feasible. When this is not feasible, the area required for treatment is only the area bounded by the roadway right-of-way.

1115.4 Water Quality Flow (WQf)

The water quality flow (WQf) is the discharge that is produced by an approximate precipitation of 0.50 inches. It is calculated by using the intensity of a 2-year, 180 minute duration storm from the intensity-duration-frequency curves given in figure 1101-2. This is the primary design criteria used for filtration treatments such as vegetated swales and filter strips.

1116 Structural Best Management Practices (BMPS)

1116.1 General

Appropriate structural BMPS shall be used to treat the water quality volume, the water quality flow, or a combination of both. The BMPS selected shall be: technically feasible, implemented within the highway right-of-way, and safe for the traveling public and ODOT maintenance personnel. All Structural BMPS shall be maintained by the Department and shall be considered drainage structures necessary for positive drainage. Routine maintenance may be necessary to ensure proper drainage. Post construction storm water management controls are sensitive to sediment laden water, therefore they should be constructed after the primary construction is completed.

The BMPS shall not compromise any Federal, State, or Local laws and must have a reasonable cost as compared to their benefit. Any BMPS that are too large to fit within the procured right-of-way are considered infeasible. Purchasing additional right-of-way is generally not fiscally responsible unless the land is undeveloped. Volumes smaller than the calculated WQf may be used with the approval of the Hydraulic Section, Office of Structural Engineering.

Example BMP designs have been provided in figures 1116-5 through 1116-12.

1116.1.1 Feasibility study

A BMP feasibility study shall be provided for all projects that have restrictions or limitations on BMP usage. The study should summarize the BMPS that were chosen (or omitted) and indicate the reasoning behind their selection. The justification should be submitted to the Hydraulic Section, Office of Structural Engineering for review and coordination with the OEP.

1116.2 Vegetated Swales and Filter Strips (WQf)

Vegetated swales and filter strips treat storm water via the interaction of vegetation with suspended solids in the storm water. Due to this interaction, the allowable flow depth is limited to the height of the vegetation, usually 6 inches. Vegetated swales can be further defined as dry and wet swales. Dry swales perform filtration only while wet swales perform filtering and provide some storage capability. The storage capacity is defined by the use of rock check dams or weirs along the swale. Vegetated Swales and Filters are primarily used for pretreatment of other structural BMPS, but may be used exclusively for smaller drainage areas which produce a WQf less than 0.1 Acre-ft. The following criteria applies to swales and filters:

A. Design using the Water Quality Flow as per section 1115.3.

B. Provide a preferred slope of less than 2% with the maximum being 5%.

C. When the slope is greater than 2%, provide check dams or weirs with a maximum height of 4 inches to reduce the effective slope to 2%.

D. Limit the maximum (water quality flow) velocity to 1.0 ft/sec.

E. The underlying soils must be suitable for healthy vegetation.

F. The ground water table must be below the flow line of the (dry) swale or strip.

1116.2.1 Dry or Wet Vegetated Swales

Swales are trapezoidal channels with bottom widths that usually range from 2 to 25 feet and have side slopes no steeper than 3:1. The preferred minimum length is 100 feet (if feasible). Adequate care should be taken to dissipate the