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December 2016

Application for Certification

Data Adequacy Supplement

For the

Stanton Energy Reliability Center

Submitted to:

CALIFORNIA ENERGY COMMISSION

Submitted by:

Stanton Energy Reliability Center, LLC

With technical assistance by:

ch2m

2485 Natomas Park Drive, Suite 600 Sacramento, CA 95833

December 21, 2016

Mr. John Heiser Project Manager Siting, Transmission and Environmental Protection Division California Energy Commission 1516 Ninth Street, MS-15 Sacramento, CA 95814-5512

Subject: Stanton Energy Reliability Center (16-AFC-01) Data Adequacy Supplement

Dear Mr. Heiser:

Please find attached the Stanton Energy Reliability Center Application for Certification (16-AFC-01) Data Adequacy Supplement. This supplement was prepared in response to the Staff's Data Adequacy Recommendation dated November 29, 2016.

Attached are 2 hard copies and 2 electronic copies on CD-ROM.

If you have any questions about this matter, please contact me at (916) 492-9486.

Sincerely,

Stanton Energy Reliability Center, LLC

Kara J. Miles President

650 Bercut Drive, Suite A Sacramento, CA 95811



Application for Certification

Data Adequacy Supplement

For the

Stanton Energy Reliability Center

16-AFC-01

Prepared by:

Stanton Energy Reliability Center, LLC

Prepared for:

California Energy Commission

December 2016



CH2M Hill Engineers, Inc. 2485 Natomas Park Drive, Suite 600 Sacramento, CA 95833

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DA5.12-2	Air Navigation Obstruction Analysis
DA5.12-3	Thermal Plume Analysis
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DA5.15-2	Drainage Design Study

Acronyms and Abbreviations

AFC Application for Certification

CEC California Energy Commission

CEQA California Environmental Quality Act
CPUC California Public Utilities Commission

DA Data Adequacy
GO General Order

GSWC Golden State Water Company

LORS laws, ordinances, regulations, and standards

MWDOC Municipal Water District of Orange County

OCWD Orange County Water District

RO Reverse osmosis

SCAQMD South Coast Air Quality Management District

SCE Southern California Edison

SERC Stanton Energy Reliability Center

UWMP Urban Water Management Plan

Data Adequacy Supplement Introduction

This supplement to Stanton Energy Reliability Center, LLC's Application for Certification (AFC) for the Stanton Energy Reliability Center (16-AFC-01), provides additional information in response to California Energy Commission (CEC) Staff's data adequacy review of the AFC. SERC is working closely with the South Coast Air Quality Management District (SCAQMD) to obtain a completeness letter for the Application for Determination of Compliance. The SCAQMD letter will be forwarded under separate cover when obtained. With the additional information contained in this supplement and with the SCAQMD completeness letter, Staff should recommend that the AFC contains adequate data to begin a power plant site certification proceeding under Title 20, California Code of Regulations and the Warren-Alquist Energy Resources Conservation and Development Act.

The format for this supplement follows the order of the AFC. Only AFC sections for which CEC Staff posed requests or questions related to data adequacy are addressed in this supplement. If the response calls for additional material, it is included as an attachment at the end of the applicable subsection. Attached material is identified by the prefix "DA" indicating an item submitted in response to a Staff Data Adequacy comment, a number referring to the applicable AFC chapter, and a sequential identifying number. For example, the first sequential attachment in response to a Transmission System Engineering comment would be Attachment DA3.0-1, because the AFC section describing electrical transmission is Section 3.0. Attached material is paginated separately from the document text.

Each subsection references the data adequacy information request followed by a response to the information request.

1.0 Introduction/Project Overview

1. Site Location - Appendix B (a) (1) (B)

Identification of the location of the proposed site and related facilities by section, township, range....

Information required to make AFC conform with regulations:

Please provide the section, township and range for the project location.

Response: Township 4 South, Range 11 West, Section 24.

2. Leaseholds Location - Appendix B (a) (1) (A)

Identification of the dedicated leaseholds by section, township, range....

Information required to make AFC conform with regulations:

Please provide dedicated leaseholds by section, township and range.

Response: Township 4 South, Range 11 West, Section 24.

2.0 Project Description

3. Technology Availability - Appendix B (h) (3) (B) (v)

For technologies not previously installed and operated in California, the expected power plant maturation period.

Information required to make AFC conform with regulations:

In addition to the natural gas-fired, simple-cycle power trains, the project proposes battery energy storage systems for onsite storage of electricity that can deliver additional electricity to the electricity grid. The project also proposes a clutch system to provide voltage support by operating as a synchronous condenser.

The integration of these energy storage and clutch/condenser systems into thermal power plants is new in California. Please explain how the integration of these systems into the project's design would ensure the project's expected availability factor of 92-98 percent is achievable and maintained during the life of the project.

Response: SERC is comprised of two LM6000 EGT™ Hybrids, with each EGT™ Hybrid comprised of an LM6000 natural gas-fired combustion turbine, with a clutch, and an integrated battery storage system. As such, the battery storage systems are not intended to have independent operation nor provide additional energy to the grid in excess of each LM6000's capability. Also the battery systems are not expected to increase or reduce forced or scheduled outages nor moderate (either positively or negatively) the availability of the LM6000s or the overall project. Even in the event the battery systems were to become unavailable, the LM6000s would remain available.

However, the integrated EGT™ Hybrid units are expected to provide a broader range of reliability services than a conventional peaker, which is the ultimate objective of the integration of the battery storage systems to form EGT™ Hybrids.

During most years, SERC expects an annual availability in excess of 98 percent but, in some years, SERC expects an annual availability of 92 to 98 percent, which includes an allowance for scheduled and forced outages. The project's availability will largely be governed by the availability of the LM6000s, which are operated abundantly in California.

The project's LM6000 natural gas-fired combustion turbine technology has been in use for decades and the LM6000's availability at more than 98 percent is well established by the manufacturer, GE Energy, and is based on more than 100 million operating hours. Similarly, the clutch system that allows the plant to operate as a synchronous condenser is already a mature technology as it has been commercially deployed for a long period of time. The first major gas turbine-driven generator/synchronous condenser entered commercial service in 1964. The first use on a GE LM6000 dates back to 1999. Clutch systems are also common in compressed air and pump water energy storage projects. Given this wide use and long history, the clutch system is expected to have minimal impact to the annual availability of the SERC gas turbines.

3.0 Transmission System Engineering

4. Transmission Facilities - Appendix B (i) (2) (A)

A discussion of the need for the additional electric transmission lines, substations, or other equipment, the basis for selecting principal points of junction with the existing electric transmission system, and the capacity and voltage levels of the proposed lines, along with the basis for selection of the capacity and voltage levels.

Information required to make AFC conform with regulations:

Substation information:

- Provide a detail one-line diagram of the proposed project on-site plant substation with proper ratings of the equipment.
- Resubmit figure 3.2-1 69 kV, Typical transmission tower design, with dimensions, pole configuration and indicate the number of poles that are necessary to interconnect the project to the SCE grid.
- Provide a detailed one-line diagram of the existing SCE Barre substation with proper equipment ratings and indicate the project interconnection point with bay arrangements. Provide detailed information on the necessary components and their ratings.
- Provide a one-line diagram of the project overhead generator tie line interconnection point with SCE grid. Indicate necessary components and their ratings.

Battery project:

- Provide schematic diagrams of the 10 MW battery project with detailed information on how it would interconnect to the on-site plant substation.
- Discuss the method of operation of the 10 MW battery storage at different times of day describe and how it would be utilized for voltage and frequency regulation within these time frames.

Response: Attachment DA3.0-1 contains a one-line diagram of the overall SERC project with ratings, including the generator tie-line interconnection point with the SCE grid. A detailed one-line diagram of the existing SCE Barre substation is proprietary to, and not available from, SCE.

AFC Figure 3.2-1 includes dimensions and shows pole configuration and therefore is not resubmitted. A single pole will be used for interconnection as the remainder of the generator tie-line will be constructed underground.

Regarding the battery project, please see Response #8.

5. Transmission Requirements - Appendix B (i) (2) (B)

A discussion of the extent to which the proposed electric transmission facilities have been designed, planned, and routed to meet the transmission requirements created by additional generating facilities planned by the applicant or any other entity.

Information required to make AFC conform with regulations:

Substation information:

• Resubmit figure 3.2-1 69 kV, Typical transmission tower design, with dimensions, pole configuration and indicate the number of poles that are necessary to interconnect the project to the SCE grid.

- Provide a detailed one-line diagram of the existing SCE Barre substation with proper equipment ratings and indicate the project interconnection point with bay arrangements. Provide detailed information on the necessary components and their ratings.
- Provide a one-line diagram of the project overhead generator tie line interconnection point with SCE grid. Indicate necessary components and their ratings.

Battery project:

• Provide schematic diagrams of the 10 MW battery project with detailed information on how it would interconnect to the on-site plant substation.

Response: Attachment DA3.0-1 contains a one-line diagram of the overall SERC project with ratings, including the generator tie-line interconnection point with the SCE grid. A detailed one-line diagram of the existing SCE Barre substation is proprietary to, and not available from, SCE.

AFC Figure 3.2-1 includes dimensions and shows pole configuration and therefore is not resubmitted. A single pole will be used for interconnection as the remainder of the generator tie-line will be constructed underground.

Regarding the battery project, please see response #8.

6. Transmission Design - Appendix B (i) (2) (C)

A detailed description of the design, construction, and operation of any electric transmission facilities, such as power lines, substations, switchyards, or other transmission equipment, which will be constructed or modified to transmit electrical power from the proposed power plant to the load centers to be served by the facility. Such description shall include the width of rights of way and the physical and electrical characteristics of electrical transmission facilities such as towers, conductors, and insulators. This description shall include power load flow diagrams which demonstrate conformance or nonconformance with utility reliability and planning criteria at the time the facility is expected to be placed in operation and five years thereafter....

Information required to make AFC conform with regulations:

Substation information:

- Provide a detail one-line diagram of the proposed project on-site plant substation with proper ratings of the equipment.
- Resubmit figure 3.2-1 69 kV, Typical transmission tower design, with dimensions, pole configuration and indicate the number of poles that are necessary to interconnect the project to the SCE grid.
- Provide a detailed one-line diagram of the existing SCE Barre substation with proper equipment ratings and indicate the project interconnection point with bay arrangements. Provide detailed information on the necessary components and their ratings.
- Provide a one-line diagram of the project overhead generator tie line interconnection point with SCE grid. Indicate necessary components and their ratings.

Battery project:

- Provide schematic diagrams of the 10 MW battery project with detailed information on how it would interconnect to the on-site plant substation.
- Discuss the method of operation of the 10 MW battery storage at different times of day describe and how it would be utilized for voltage and frequency regulation within these time frames.

Response: Attachment DA3.0-1 contains a one-line diagram of the overall SERC project with ratings, including the generator tie-line interconnection point with the SCE grid. A detailed one-line diagram of the existing SCE Barre substation is proprietary to, and not available from, SCE.

AFC Figure 3.2-1 includes dimensions and shows pole configuration and therefore is not resubmitted. A single pole will be used for interconnection as the remainder of the generator tie-line will be constructed underground.

Regarding the battery project, please see response #8.

7. Laws, Ordinances, Regulations, and Standards (LORS) Applicability - Appendix B (h) (1) (A)

Tables which identify laws, regulations, ordinances, standards, adopted local, regional, state, and federal land use plans, and permits applicable to the proposed project, and a discussion of the applicability of each. The table or matrix shall explicitly reference pages in the application wherein conformance, with each law or standard during both construction and operation of the facility is discussed;

Information required to make AFC conform with regulations:

Need to discuss "underground and overhead electric line construction" CPUC- G.O.128 and G.O. 95

Response: Table DA3.0-1 lists CPUC G.O. 128 and G.O. 95 and indicates their applicability to the SERC project.

Table DA3.0-1. Design and Construction LORS for the Proposed Transmission Line and Switchyard

LORS	Applicability	
G.O. 128	Provides detailed rules and specifications for underground electric supply and communication system construction	
G.O. 95	Provides detailed rules and specifications for overhead electric line construction	

8. Permits Required - Appendix B (h) (4)

A schedule indicating when permits outside the authority of the commission will be obtained and the steps the applicant has taken or plans to take to obtain such permits.

Information required to make AFC conform with regulations:

The Interconnection Study Reports need to include the battery storage portion of the project. Additional Voltage/Var support provided by the 10MW battery project needs to be evaluated by SCE, and a sensitivity study for Voltage/Var support provided. The study should indicate adjacent SCE system is stable post project after the 10MW storage is added.

Response: The interconnection process for the SERC has followed the iterative design of the project. See Section 1.1 of the AFC for a description of SERC's Project Objectives and a description of the 2013 and 2014 SCE RFO processes that led to the SERC as currently proposed.

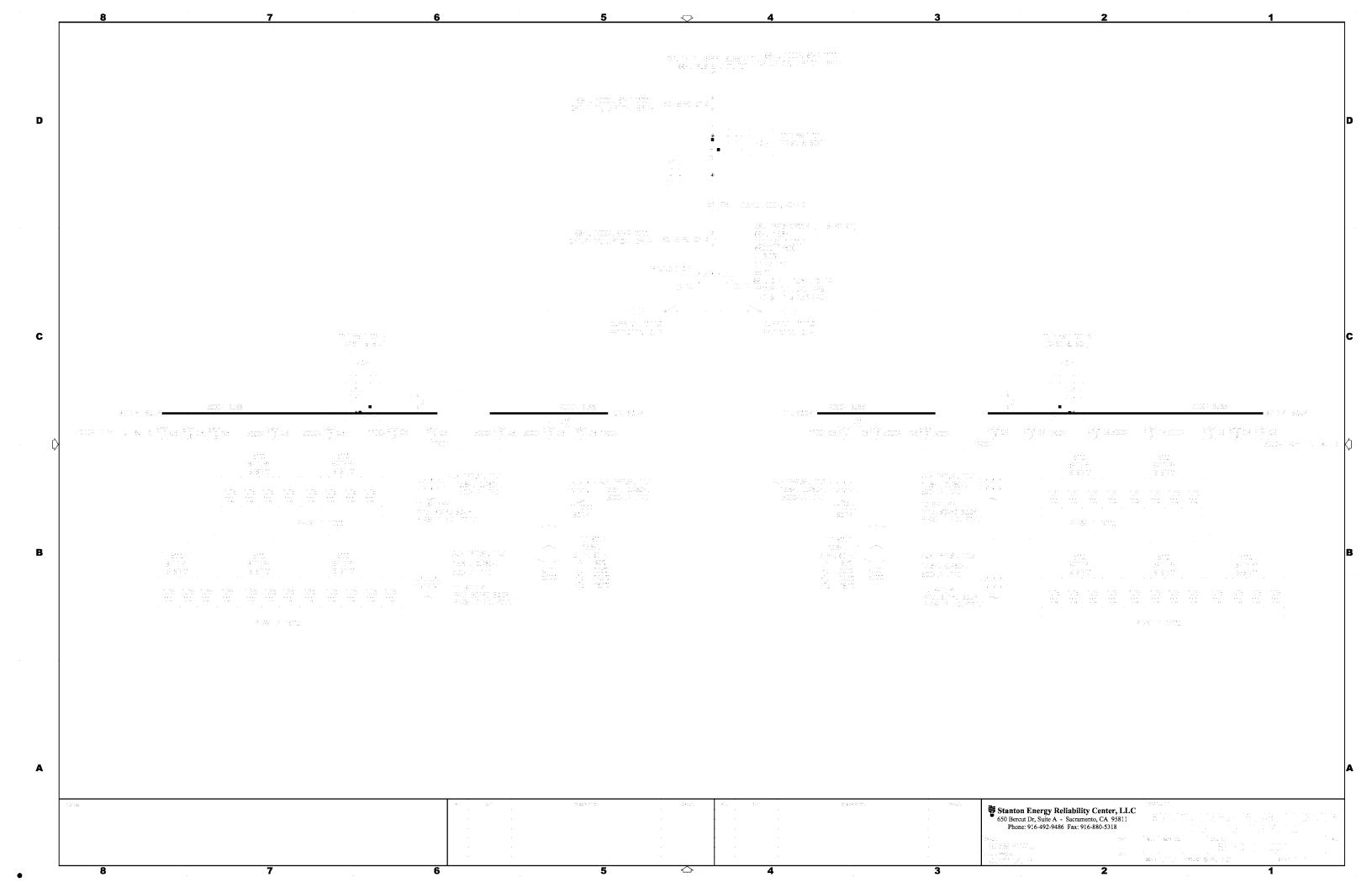
SERC has three active interconnection requests that cover the facilities that will be constructed pursuant to the Project Objectives.

- A Cluster 7 Interconnection Request ("IR"), WDT1187, was filed before SCE had made any decisions in any of the competitive procurements (including the aforementioned RFO processes). In that IR, the SERC was initially envisioned as including up to 150 MW of gas-fired electrical generation interconnecting into the SCE Barre Substation at the 66 kV bus.
- After determining the potential need for energy storage attributes, SERC subsequently filed an IR in Cluster 8, WDT1293, in order to determine if there would be any charging or voltage stability issues

- if 20 MW of energy storage were developed at the SERC site in lieu of (or in addition to) the 150 MW of synchronous generation.
- Ultimately, when the SERC was further refined to be an EGT™, SERC then filed an IR in Cluster 9
 (WDT1391), which conformed and consolidated the previous IR's with a project configuration of two
 EGT™s (two LM6000s and 20 MWs of integrated storage equaling 98 MWs with up to a total of 50
 MW of storage) into a single interconnection request. The Phase 1 study for this IR is expected to be
 delivered by SCE to SERC in January 2017.

All three of these Interconnection Requests (Interconnection Queue Positions) sought to deliver energy/services to the same Energy Delivery Point – the Barre 66 kV bus.

Attachment DA3.0-1 One-Line Diagram



5.1 Air Quality

9. Air Pollution Control District Application - Appendix B (g) (8) (A)

The information necessary for the air pollution control district where the project is located to complete a Determination of Compliance.

Information required to make AFC conform with regulations:

Please provide a copy of the letter of completeness from South Coast Air Quality Management District.

Response: The South Coast Air Quality Management District (SCAQMD) will provide the determination of completeness letter to the CEC.

10. Cumulative Air Impacts Protocol - Appendix B (g) (8) (l) (iii)

A protocol for a cumulative air quality modeling impacts analysis of the project's typical operating mode in combination with other stationary emissions sources within a six mile radius which have received construction permits but are not yet operational, or are in the permitting process. The cumulative inert pollutant impact analysis should assess whether estimated emissions concentrations will cause or contribute to a violation of any ambient air quality standard...

Information required to make AFC conform with regulations:

Please provide a protocol for cumulative modeling analysis.

Response: AFC Appendix 5.1G provides the Cumulative Air Quality Modeling protocol.

11. Offset Quantities - Appendix B (g) (8) (j) (i)

The quantity of offsets or emission reductions that are needed to satisfy air permitting requirements of local permitting agencies (such as the air district), state and federal oversight air agencies, and the California Energy Commission. Identify by criteria air pollutant, and if appropriate, greenhouse gas...

Information required to make AFC conform with regulations:

Please identify the required quantity of offsets for each pollutant.

Response: AFC Appendix 5.1H, Table 5.1H-1 shows air emissions, by criteria pollutant. Offsets are not required for the project as offset thresholds are not exceeded.

12. Mitigation Measures - Appendix B (g) (8) (j) (ii)

Potential offset sources, including location, and quantity of emission reductions...

Information required to make AFC conform with regulations:

Please provide emissions mitigation measures required for CEQA purposes.

Response: Emission reduction credit offsets are not required for CEQA mitigation. The Applicant will work with the CEC to implement a CEQA mitigation strategy for the non-attainment pollutants and precursors such as NOx, VOCs, PM10/2.5 and SOx. The SCAQMD currently has several incentive programs that could be used to mitigate the project increase in non-attainment pollutants. These include the Vehicle and Engine Upgrade Program, the Residential EV Charging Incentive, Wood Stove and Fireplace Change-Out Incentive, Lawn Equipment Program, Tree Planting Partnership, Air Quality

Investment Program, Short Term Emission Reduction Credits, and the Mobile Source Emission Reduction Credits.

The Vehicle and Engine Upgrade Program focuses on the following incentives:

- Carl Moyer
- Goods Movement Emission Reduction Projects
- Off-Road Diesel Engine Program
- Clean School Bus Program
- Mobile Source Credits
- Voucher Incentive Program

In addition to these programs, SERC, LLC would like to discuss further with Staff the fact that the SERC, by using EGT™ Hybrids, will displace emissions from gas-fired generation during certain circumstances, such that mitigation, if required, should be discounted to account for such displacement.

5.3 Cultural Resources

13. Map of Cultural Resources - Appendix B (g) (2) (B)

A map at a scale of 1:24,000 U.S. Geological Survey quadrangle depicting the locations of all previously known and newly identified cultural resources compiled through the research required by Appendix B (q)(2)(B) and Appendix B (q)(2)(C) (ii); and

Information required to make AFC conform with regulations:

Please: a) provide all locations of previously known and newly recorded cultural resources plotted on a 1:24,000 U.S. Geological Survey quadrangle map, b) clearly distinguish between previously known and newly identified resources using legible font and text labels, c) include a map legend that clearly identifies all plotted resources, including previously known and newly identified cultural resources, buildings, structures, and districts d) submit this information to the CEC under a request for confidentiality.

Response: Figure 4 in AFC Appendix 5.3B (Cultural Resources Technical Report) shows the locations of the cultural resources properties that are in the area of potential effects (locations adjacent to or near the facility site). These are all newly recorded properties. Properties identified in the literature search as being within 1 mile of the project site and 0.25 mile of the linear appurtenances are all more than 2,000 feet from the facility site and are all properties of the built environment that would not be affected by an underground pipeline. Per CEC data adequacy regulations, the historic built environment survey covers the area "one-parcel deep" adjacent to the facility site and generator tie-line. All of the previously recorded properties are outside of this area.

Attachment DA5.3-1 is a map at a scale of 1:24,000 showing the locations of the previously recorded and newly recorded properties in relation to the literature search area, pedestrian search area, facility site, and gas pipeline. This map has been submitted separately to the CEC under a request for confidentiality.

Attachment DA5.3-1 USGS Quadrangle Map (filed separately)

This information has been filed separately under a request for confidential designation.			

5.5 Geological Hazards and Resources

14. Natural Gas Pipeline - Appendix B (g) (17) (B)

A map at a scale of 1:24,000 and description of all recognized stratigraphic units, geologic structures, and geomorphic features within two (2) miles of the project site and along proposed facilities. Include an analysis of the likelihood of ground rupture, seismic shaking, mass wasting and slope stability, liquefaction, subsidence, tsunami runup, and expansion or collapse of soil structures at the plant site. Describe known geologic hazards along or crossing linear facilities.

Information required to make AFC conform with regulations:

Please provide a site-specific discussion of geologic hazards along or crossing the proposed gas pipeline.

Response: The geological and soil conditions along and crossing the proposed natural gas pipeline are the same as those underlying the facility site and therefore the geological hazards for the pipeline are the same as those described in the AFC for the facility site. The geology of the entire area consists of young Quaternary alluvium, the soils are sandy loams and loamy sands, and the topography is flat. There are no earthquake faults that cross the pipeline or the facility site. The site and pipeline routes have similar liquefaction potential. The gas pipeline routes are not subject to mass wasting or expansive soil hazards.

15. Agency Jurisdiction - Appendix B (i) (1) (B)

Tables which identify each agency with jurisdiction to issue applicable permits, leases, and approvals or to enforce identified laws, regulations, standards, and adopted local, regional, state and federal land use plans, and agencies which would have permit approval or enforcement authority, but for the exclusive authority of the commission to certify sites and related facilities.

Information required to make AFC conform with regulations:

Please add Orange County Fire Authority to the LORS table as they are required to review construction drawings per the Plan Submittal Guidelines: Commercial Alteration/Addition of the City of Stanton Building Regulation.

Response: The Orange County Fire Authority (OCFA) contact information is provided in Tables 5.5-6 (Hazardous Materials Management AFC section) and 5.16-6 (Worker Health and Safety AFC section). It was not included in the Geological Hazards and Resources AFC section also as there is no permit that would be required from this agency to address geological hazards. The contact information is provided in Table DA5.5-1.

Table DA5.5-1. OCFA Agency Contacts

Issue	Agency	Contact
Fire Department Permits	OCFA	Linda Martinez Orange County Fire Authority Planning and Development Services 1 Fire Authority Road Irvine, CA 93602 (714) 573-6145

Table DA5.5-1. OCFA Agency Contacts

Issue	Agency	Contact
Hazardous Materials Response	OCFA	Mike Morganstern, Battalion Chief Station 79 Santa Ana 1320 East Warner Avenue Santa Ana, CA 92705 (714) 567-3236

16. Agency Contact - Appendix B (i) (2)

The name, title, phone number, address (required), and email address (if known), of an official who was contacted within each agency, and also provide the name of the official who will serve as a contact person for Commission staff.

Information required to make AFC conform with regulations:

Please provide contact information for City of Stanton and Orange County Fire Authority

Response: City of Stanton contact information is included in Table 5.6-6 (Land Use AFC section). The OCFA contact information is provided in Tables 5.5-6 (Hazardous Materials Management AFC section) and 5.16-6 (Worker Health and Safety AFC section). This information was not included in the Geological Hazards and Resources AFC section also as there is no permit that would be required from this agency to address geological hazards.

5.10 Socioeconomics

17. Operation Payroll - Appendix B (g) (7) (B) (vii)

An estimate of the total construction payroll and separate estimates of the total operation payroll for permanent and short-term (contract) operations employees...

Information required to make AFC conform with regulations:

Provide estimated operation payroll for all permanent and short-term employees.

Response: AFC Section 5.10.2.4 provides the operational payroll for operations employees. All operations employees will be full- or part-time and long-term employees. There will be no short-term (contract) operations employees.

5.12 Traffic and Transportation

18. FAA Regulation Part 77 - Appendix B (g) (5) (B)

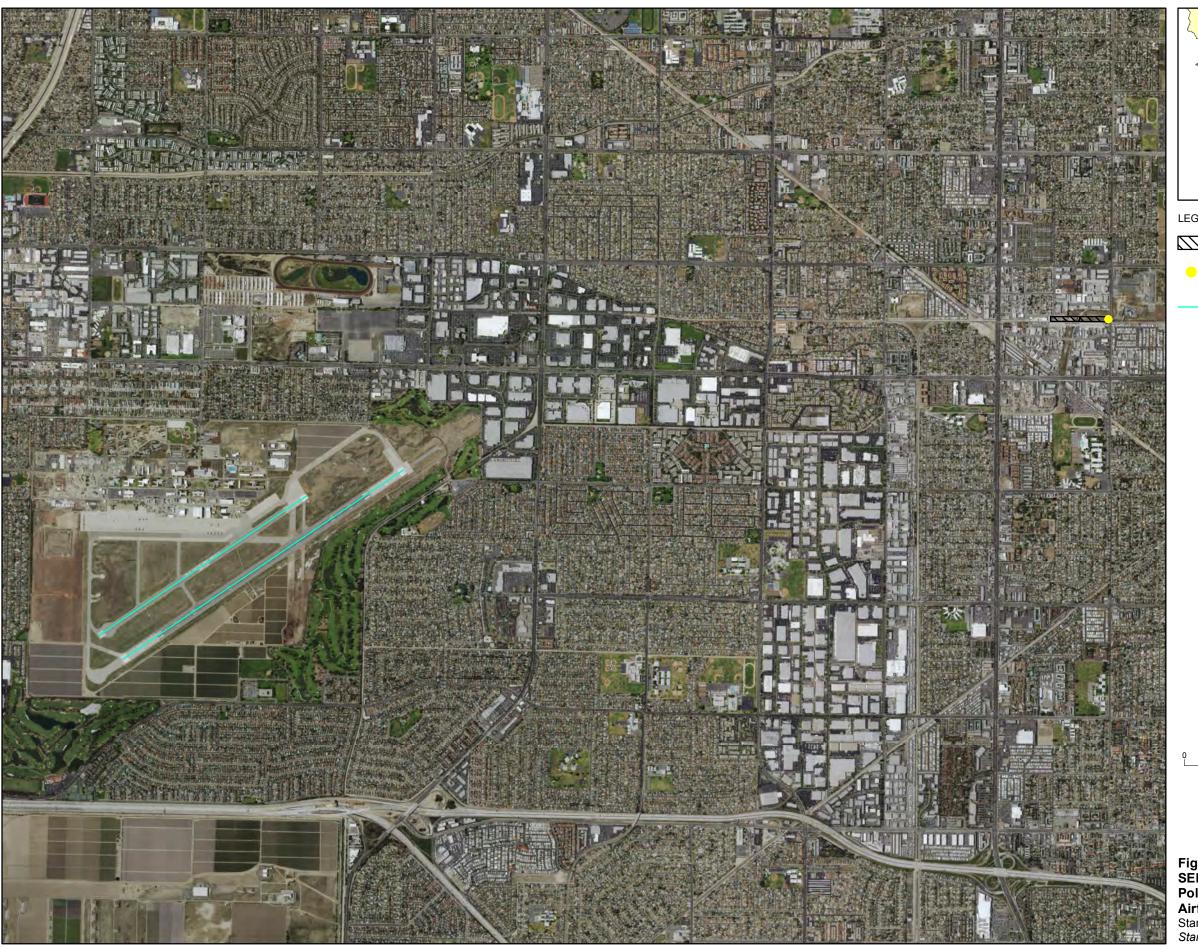
If the proposed project including any linear facility is to be located within 20,000 feet of an airport runway that is at least 3,200 feet in actual length, or 5,000 feet of a heliport (or planned or proposed airport runway or an airport runway under construction, that is the subject of a notice or proposal on file with the Federal Aviation Administration), discuss the project's compliance with the applicable sections of the current Federal Aviation Regulation Part 77 – Objects Affecting Navigable Airspace, specifically any potential to obstruct or impede air navigation generated by the project at operation; such as, a thermal plume, a visible water vapor plume, glare, electrical interference, or surface structure height. The discussion should include a map at a scale of 1:24,000 that displays the airport or airstrip runway configuration, the proposed power plant site and related facilities.

Information required to make AFC conform with regulations:

The Los Alamitos Army Airfield is located approximately 15,500 feet southwest of the SERC site and has two runways: one 7,999 feet long and the other 5,901 feet long. The AFC states (pg. 5.12-18): "An Obstruction Evaluation and Airspace Analysis is being conducted for SERC to identify obstacle clearance surfaces established by the FAA that could result in determination of hazards for the 70-foot high exhaust stacks..." In addition, operation of the project's two turbine generators would create thermal plumes, but the AFC does not include a discussion of the potential for thermal plumes to affect air navigation in the airspace above the exhaust stacks for pilots arriving to and departing from the Los Alamitos Army Airfield. Please provide a discussion of the project's compliance with Federal Aviation Regulation Part 77 regarding structure heights, construction cranes and an analysis of the potential for the proposed project's thermal plumes to affect air navigation. In addition, please provide a 1:24,000 scale map that shows the Los Alamitos Army Airfield runway configuration, the proposed project site, and related facilities (e.g., power lines).

Response: Attachment DA5.12-1 is a map at a scale of 1:24,000 showing the project site and generator tie-line pole (there is only one pole) in relation to the airfield runways at Joint Forces Training Base, Los Alamitos. Attachment DA5.12-2 is a detailed analysis of the potential for the project to cause air navigation obstructions, in relation to the FAA Part 77 regulations. Attachment DA5.12-3 is an analysis of velocity of thermal plumes extending from the SERC stacks.

Attachment DA5.12-1 Joint Forces Training Base, Los Alamitos, Airfield





LEGEND

Project Site

Location of Transmission Tower

Joint Forces Training Base - Los Alamitos Runway Line



Figure DA5.3-1
SERC Project Site and Generator Tie-Line
Pole in Relation to Los Alamitos Army
Airfield Runways
Stanton Energy Reliability Center AFC
Stanton, California



Attachment DA5.12-2 Air Navigation Obstruction Study

Stanton Energy Reliability Center

Stanton Energy Reliability Center, LLC Orange County, California

Obstruction Evaluation & Airspace Analysis

August 15, 2016





Summary

Capitol Airspace conducted an obstruction evaluation and airspace analysis for the Stanton Energy Reliability Center (Stanton) project in Orange County, California. The purpose for this analysis was to identify obstacle clearance surfaces established by the Federal Aviation Administration (FAA) that could result in determinations of hazard for 70 foot above ground level (AGL) turbine stacks. This study also assessed height constraints overlying an approximately four acre study area to aid in identifying optimal turbine stack locations.

The FAA requires that all structures exceeding 14 CFR Part 77.9 notice criteria be submitted to the FAA so that an aeronautical study can be conducted. The FAA's objective in conducting aeronautical studies is to ensure that proposed structures do not have an effect on the safety of air navigation and the efficient utilization of navigable airspace by aircraft. The end result of an aeronautical study is the issuance of a determination of 'hazard' or 'no hazard' that can be used by the proponent to obtain necessary local construction permits. It should be noted that the FAA has no control over land use in the United States and cannot enforce the findings of its studies.

Height constraints overlying the Stanton project are a constant 260 feet above mean sea level (AMSL) and are associated with instrument approach procedures. Proposed structures that exceed 260 feet AMSL would require an increase to circling minimum descent altitudes. If the FAA determines this increase would affect a significant volume of operations, it could be used as the basis for determinations of hazard.

United States Geological Survey (USGS) elevation data indicates that this surface should not limit 70 foot AGL turbine stacks within the defined study area.

This study did not consider electromagnetic interference on communications, navigation, or radar surveillance systems.

Capitol Airspace applies FAA defined rules and regulations applicable to obstacle evaluation, instrument procedures assessment and visual flight rules (VFR) operations to the best of its ability and with the intent to provide the most accurate representation of limiting airspace surfaces as possible. Capitol Airspace maintains datasets obtained from the FAA which are updated on a 56 day cycle. The results of this analysis/map are based on the most recent data available as of the date of this report. Limiting airspace surfaces depicted in this report are subject to change due to FAA rule changes and regular procedure amendments. Therefore, it is of the utmost importance to obtain FAA determinations of no hazard prior to making substantial financial investments in this project.



Methodology

Capitol Airspace studied the proposed project based upon location information provided by Stanton Energy Reliability Center, LLC. Using this information, Capitol Airspace generated graphical overlays to determine proximity to airports (*Figure 1*), published instrument procedures, enroute airways, civil minimum vectoring altitude charts, special use airspace, and military training routes.

Capitol Airspace evaluated all 14 CFR Part 77 imaginary surfaces, published instrument approach and departure procedures, visual flight rules operations, civil minimum vectoring altitudes, and enroute operations. All formulas, headings, altitudes, bearings and coordinates used during this study were derived from the following documents and data sources:

- 14 CFR Part 77 Safe, Efficient Use, and Preservation of the Navigable Airspace
- FAA Order 7400.2K Procedures for Handling Airspace Matters
- FAA Order 8260.3C United States Standard for Terminal Instrument Approach Procedures
- FAA Order 8260.58A United States Standard for Performance Based Navigational (PBN)
 Instrument Procedure Design
- United States Government Flight Information Publication, US Terminal Procedures
- National Airspace System Resource Aeronautical Data

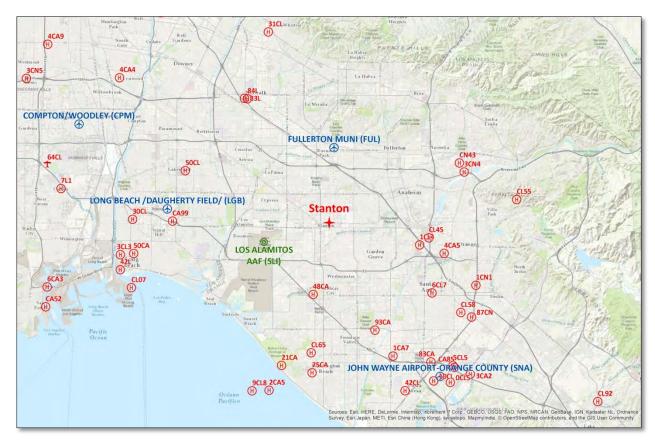


Figure 1: Public-use (blue), private-use (red), and military (green) airports and heliports in proximity to the Stanton project



Study Findings

14 CFR Part 77 Imaginary Surfaces

The FAA uses level and sloping imaginary surfaces to determine if a proposed structure is an obstruction to air navigation. Structures that are identified as obstructions are then subject to a full aeronautical study and increased scrutiny. Structures that are not identified as obstructions are, in most cases, automatically issued favorable determinations.

14 CFR Part 77 imaginary surfaces (Figure 2) overlying the Stanton project:

Los Alamitos Army Airfield (SLI)

14 CFR Part 77.17(a)(2): 296 to 321 feet AMSL

14 CFR Part 77.21: 535 feet AMSL

At 70 feet AGL, proposed turbine stacks within the defined study area would not exceed Los Alamitos Army Airfield (SLI) 14 CFR Part 77.17(a)(2) (dashed blue, *Figure 2*) or 77.21 (black, *Figure 2*) imaginary surfaces and should not be identified as obstructions.

Exceeding a Part 77 imaginary surface does not automatically result in the issuance of a determination of hazard. Proposed structures must have airspace impacts that constitute a substantial adverse effect in order to warrant the issuance of determinations of hazard.

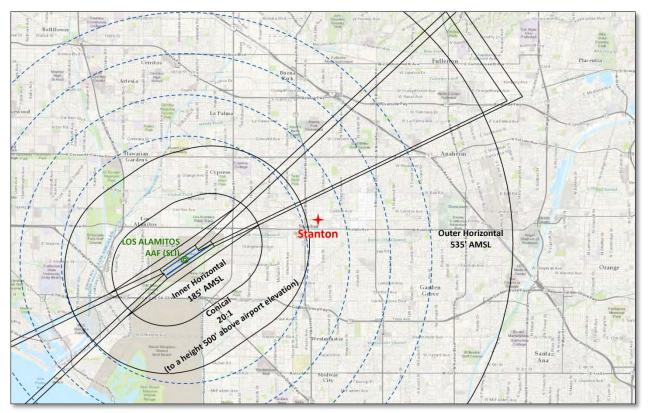


Figure 2: Los Alamitos Army Airfield (SLI) 14 CFR Part 77.17(a)(2) (dashed blue) and 77.21 (black) imaginary surfaces



Visual Flight Rules (VFR) Traffic Pattern Airspace

VFR traffic pattern airspace is used by pilots operating during visual meteorological conditions. The airspace dimensions are based upon the category of aircraft which, in turn, is based upon the approach speed of the aircraft (*Table 1*). 14 CFR Part 77.17(a)(2) and 77.19 (as applied to a *visual* runway) imaginary surfaces establish the obstacle clearance surface heights within VFR traffic pattern airspace.

Category	Approach Speed	Typical Aircraft
А	90 knots or less	Small single engine
В	Between 91 and 120 knots	Small multi engine
С	Between 121 and 140 knots	Airliner / Business Jet
D	Between 141 and 165 knots	Large Airliner / Large Business Jet
E*	166 knots or more	Certain military aircraft

^{*}The FAA does not apply above Category D VFR traffic pattern airspace

Table 1: Aircraft approach category examples

Los Alamitos Army Airfield VFR traffic pattern airspace (*Figure 3*) overlies the Stanton project. However, the associated obstacle clearance surfaces are in excess of other lower surfaces and should not limit 70 foot AGL turbine stacks within the defined study area.

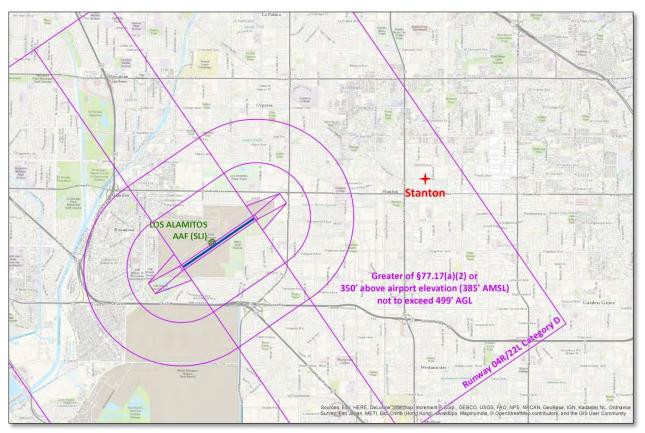


Figure 3: Los Alamitos Army Airfield (SLI) Runway 04R/22L VFR traffic pattern airspace



Instrument Departures

In order to ensure that aircraft departing during marginal weather conditions do not fly into terrain or obstacles, the FAA publishes instrument departure procedures that provide obstacle clearance to pilots as they transition between the terminal and enroute environments. These procedures contain specific routing and minimum climb gradients to ensure clearance from terrain and obstacles.

Multiple instrument departure procedures (e.g., *Figure 4*) overlie the Stanton project. However, the associated obstacle clearance surfaces are in excess of other lower surfaces and should not limit 70 foot AGL turbine stacks within the defined study area.

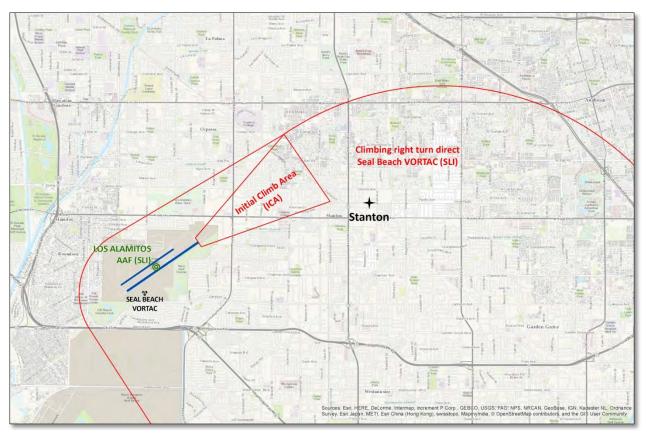


Figure 4: Los Alamitos Army Airfield (SLI) Runway 04R obstacle departure procedure assessment



Instrument Approaches

Pilots operating during periods of reduced visibility and low cloud ceilings rely on terrestrial and satellite based navigational aids (NAVAIDS) in order to navigate from one point to another and to locate runways. The FAA publishes instrument approach procedures that provide course guidance to on-board avionics that aid the pilot in locating the runway. Capitol Airspace assessed a total of 18 published instrument approach procedures at four airports in proximity to the Stanton project.

The Los Alamitos Army Airfield Category C circling approach area (red, *Figure 5*) overlies the Stanton Project. The Category C circling minimum descent altitude (CMDA) is 560 feet AMSL; the associated obstacle clearance surface is a constant 260 feet AMSL and is the lowest height constraint overlying the entire Stanton site.

Proposed turbine stacks that exceed 260 feet AMSL would require an increase to circling minimum descent altitudes. If the FAA determines this increase would affect a significant volume of operations, it could be used as the basis for determinations of hazard. However, USGS elevation data indicates that this surface should not limit 70 foot AGL turbine stacks within the defined study area.

* Los Alamitos Army Airfield has radar instrument approach procedures that likely overlie the Stanton project. Since radar instrument approach procedure documentation is not publicly available, Capitol Airspace was unable to assess impact to Los Alamitos Army Airfield radar instrument approach procedures. However, considering the existing obstacle environment, it is unlikely that the associated obstacle clearance surfaces are lower than those described in this report.



Instrument procedures assessed:

Fullerton Municipal (FUL)

RNAV (GPS) Approach to Runway 24 Localizer/DME Approach to Runway 24 VOR-A Circling Approach

Long Beach/Daugherty Field (LGB)

ILS or Localizer Approach to Runway 30 RNAV (RNP) Approach to Runway 12 RNAV (RNP) Approach to Runway 25R RNAV (RNP) Y Approach to Runway 30 RNAV (GPS) Z Approach to Runway 30 VOR or TACAN Approach to Runway 30

John Wayne Airport-Orange County (SNA)

ILS or Localizer Approach to Runway 20R RNAV (RNP) Z Approach to Runway 20R RNAV (GPS) Approach to Runway 02L RNAV (GPS) Y Approach to Runway 20R Localizer Backcourse Approach to Runway 02L LDA/DME Approach to Runway 20R

Los Alamitos Army Airfield (SLI)

RNAV (GPS) Approach to Runway 22L VOR or TACAN Approach to Runway 22L NDB Approach to Runway 22L

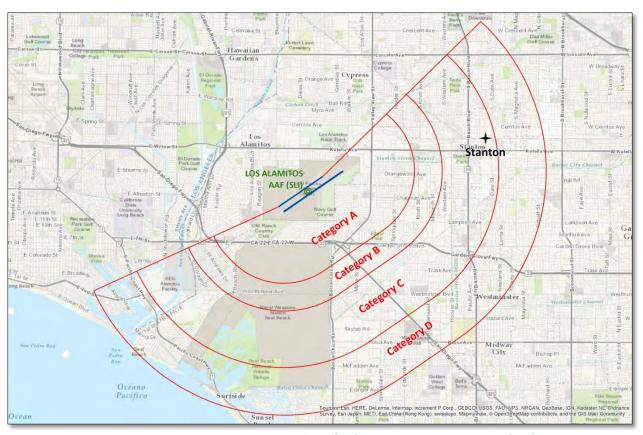


Figure 5: Los Alamitos Army Airfield (SLI) circling approach areas (red)



Enroute Airways

Enroute airways provide pilots a means of navigation when flying from airport to airport and are defined by radials between VHF omni-directional ranges (VORs). The FAA publishes minimum altitudes for airways to ensure clearance from obstacles and terrain. The FAA requires that each airway have a minimum of 1,000 feet of obstacle clearance in non-mountainous areas and normally 2,000 feet in mountainous areas.

Multiple low altitude enroute airways overlie the Stanton project (e.g., *Figure 6*). However, their associated obstacle clearance surfaces are in excess of other lower surfaces and should not limit 70 foot AGL turbine stacks within the defined study area.



Figure 6: Low altitude enroute chart L-4 with V21 obstacle evaluation area (purple)



Minimum Vectoring/IFR Altitudes

The FAA publishes minimum vectoring altitude (MVA) and minimum instrument flight rules (IFR) altitude charts that define sectors with the lowest altitudes at which air traffic controllers can issue radar vectors to aircraft based on obstacle clearance. The FAA requires that sectors have a minimum of 1,000 feet of obstacle clearance in non-mountainous areas and normally 2,000 feet in mountainous areas.

Southern California (SCT) Terminal Radar Approach Control (TRACON) minimum vectoring altitude sectors (e.g., *Figure 7*) overlie the Stanton project. However, the associated obstacle clearance surfaces are in excess of other lower surfaces and should not limit 70 foot AGL turbine stacks within the defined study area.

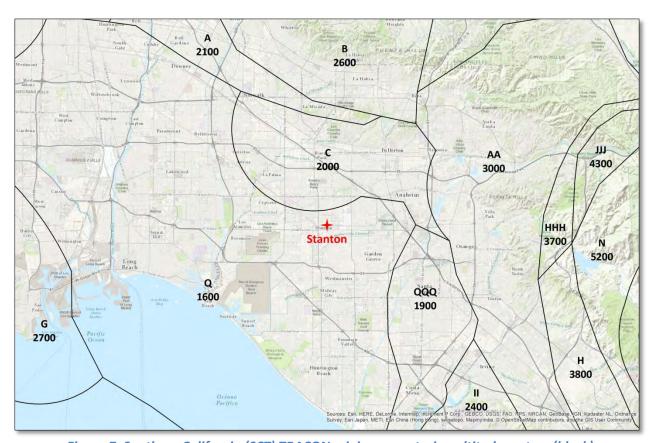


Figure 7: Southern California (SCT) TRACON minimum vectoring altitude sectors (black)

Military Airspace and Training Routes

Since the FAA does not protect for military airspace or training routes, impact on their operations cannot result in a determination of hazard. However, the FAA will notify the military of proposed structures located within these segments of airspace. If the planned development area is located on federal land, impact on military airspace or training routes may result in the denial of permits by the Bureau of Land Management.

Military airspace and training routes do not overlie the Stanton project. Therefore, these segments of airspace should not result in military objections to proposed development.



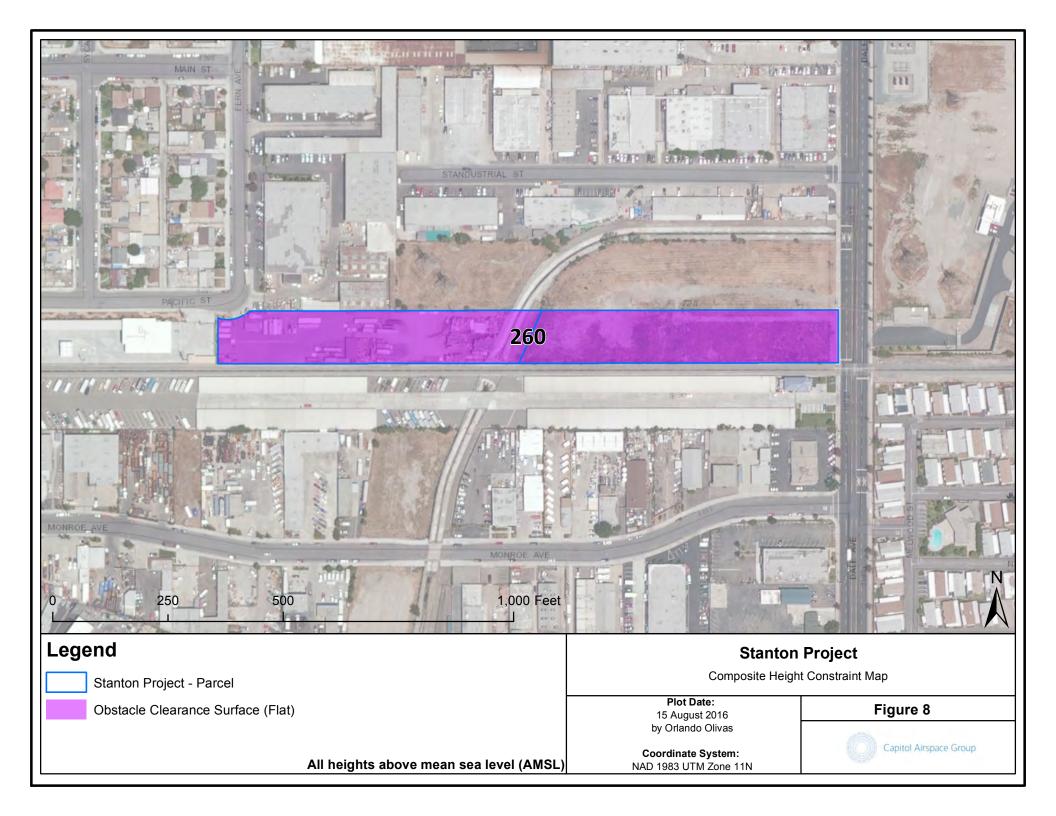
Conclusion

At 70 feet AGL, proposed turbine stacks would not exceed any 14 CFR Part 77.17(a)(2) or Part 77.19 imaginary surfaces (*Figure 2*) and should be able to receive favorable *Does Not Exceed* determinations. If further development is planned, proposed turbine stacks that exceed 14 CFR Part 77 imaginary surfaces will be identified as obstructions. However, heights in excess of these surfaces are feasible provided proposed turbine stacks do not exceed FAA obstacle clearance surfaces.

Obstacle clearance surfaces overlying the Stanton project are a constant 260 feet AMSL (*Figure 8*) and are associated with Los Alamitos Army Airfield instrument approach procedures (*Figure 5*). Proposed turbine stacks that exceed 260 feet AMSL would require an increase to circling minimum descent altitudes. If this increase would affect a significant volume of operations, it could be used as the basis for determinations of hazard. However, USGS elevation data indicates that this surface should not limit 70 foot AGL turbine stacks within the defined study area.

Cranes exceeding proposed turbine stack heights must also receive favorable determinations of no hazard. If temporary cranes required to construct the Stanton project exceed FAA obstacle clearance surfaces, they may not receive favorable temporary determinations of no hazard based on impact on Los Alamitos Army Airfield operations.

If you have any questions regarding the findings of this study, please contact *Vinnie Khera* or *Orlando Olivas* at (703) 256-2485.



Attachment DA5.12-3 Thermal Plume Analysis

Vertical Plume Velocity Assessment

Stanton Energy Reliability Center

Stanton, California

Submitted to

California Energy Commission Sacramento, CA

Submitted by

Stanton Energy Reliability Center, LLC 650 Bercut Drive, Suite A Sacramento, CA 95811

Prepared by **Atmospheric Dynamics, Inc.**



December 2016

Introduction

The Stanton Energy Reliability Center (SERC) will use two (2) LM6000 PG Sprint natural gas-fired combustion turbine generators (CTG) to generate electricity for the Southern California grid. The SERC site is located at 10711 Dale Avenue in the city of Stanton, CA on two parcels totaling approximately 4-acres. An analysis of the stack thermal exhaust plume characteristics was prepared in response to a California Energy Commission (CEC) information request regarding whether thermal plumes from SERC could create turbulence for low flying aircraft. A vertical plume velocity screening analysis of the plume characteristics was prepared based on the worst-case (100 percent load) CTG stack parameters for a cold winter day (40°F), a hot summer day (102.7°F), and annual average conditions (65°F).

Vertical plume velocities were calculated based on two methodologies: Spillane and Briggs. This analysis and summary report do not identify whether the SERC plume velocities represent a hazard to air navigation. Rather, this analysis identifies the potential for the plume velocity to exceed standard significance thresholds through a vertical cross-section of the atmosphere. No aircraft traffic patterns were assessed or considered in this evaluation.

Vertical plume velocity guidelines

There are a limited number of methodologies that have been used to assess the magnitude and heights of vertically released plumes from combustion sources.

The assessments presented in this report are based on both the Spillane methodology outlined in the "Aviation Safety and Buoyant Plumes" paper (Best, 2003) and the Briggs gradual plume rise calculations (Reisman and LeCureux, 2001) that have been used in the regulatory environment for assessing air pollution impacts. The Spillane methodology is also recognized for providing conservative assessments of aviation safety as set out by the Australian Civil Aviation Safety Authority (CASA) in their original 2004 Advisory Circular (CASA, 2004). Since this type of assessment (based on calm conditions) is overly conservative, representing meteorological conditions that occur a limited number of hours each year, a second assessment, based on Briggs gradual plume rise equations for near-calm (0.5 meters/second, m/s) horizontal wind speed conditions, is also assessed and presented later.

The aim of this assessment is to determine the potential for severe turbulence generated by the project's exhaust plumes to occur at elevations where they could pose a hazard to air navigation. The Spillane method uses worst-case assumptions of calm winds (wind speeds of 0.0 meters/second) and neutral atmospheric conditions for the entire vertical extent of the plume to determine these worst-case impacts. It should be noted that these results are conservative in that calm conditions throughout the lower levels of the atmosphere typically only occur during a limited number of hours each year.

CASA has taken an active role in the review of the siting of facilities with the potential to affect aviation activities since the mid-1990s. Potential hazards that could potentially affect the safety of aircraft include tall visible or invisible obstructions. Visible obstructions include structures such as tall stacks or communication towers. Invisible obstructions include industrial exhausts that generate significant turbulence due to high velocity and buoyancy, such as simple-cycle gas turbines. CASA has issued Advisory Circulars, (CASA 2004 and 2012) that specify the requirements and methodologies to be used to assess whether a new industrial plume is likely to have adverse implications for aviation safety.



The general CASA requirement is to determine the height at which the plume (or plumes) could generate atmospheric turbulence and to determine the dimensions of the plume in these circumstances. The frequency of in-plume vertical velocities at the lowest height an aircraft may travel over the site, and at other heights are also required. A screening-level assessment can also be made that would conservatively calculate the heights at which the turbulence could be generated. This screening-level assessment assumes a perfectly calm atmosphere with wind speeds set to zero. If the screening level analysis indicates the potential for high velocity plumes, then the next step in the analysis would be to use a more advanced modeling technique featuring actual three-dimensional site meteorology. Since plume rise and lateral dispersion are highly dependent on crosswind velocity and direction and the temperature differential between the plume and ambient air, the advanced assessment requires the use of site specific metrological data throughout the full height of the plume.

Rather than use such a refined technique, a conservative screening analysis based on calm wind field assumptions was used for this project per the original and updated CASA guidance documents (CASA, 2004 and 2012). The 2004 CASA guidance indicated that "exhaust plumes with a vertical gust in excess of the 4.3 meters per second (m/s) threshold may cause damage to an aircraft airframe, or upset an aircraft when flying at low levels." However, according to a report prepared by the Airport Cooperative Research Program (ACRP), CASA was unable to verify the source of this threshold.

The aim of this screening assessment is to conservatively determine the potential for turbulence generated by the turbine exhaust plumes. Part 139.370 of the Australian Civil Aviation Safety Regulations (1998, 2004) provides that CASA may determine that plume velocities in excess of 4.3 m/s is or will be a potential hazard to aircraft operations. The *Manual of Aviation Meteorology* (Australian Bureau of Meteorology 2003) defines severe turbulence as a vertical wind gust velocity in excess of 10.6 m/s. The assumed critical vertical velocity used as a CEC significance threshold is 5.3 meters per second¹ (m/s) but it should be noted that the basis of the original CASA derived threshold of 4.3 m/s has been lost in antiquity and that CASA no longer relies on the 1998 and 2004 regulations that established this critical threshold other than to note that a more rigorous analysis, which includes site specific meteorology, should be used if the 4.3 m/s and 10.6 m/s screening thresholds are exceeded. The screening method uses absolute worst-case assumptions of calm winds and neutral atmospheric conditions for the entire vertical extent of the plume to determine these worst-case impacts. It should be noted that these results are extremely conservative in that these worst-case conditions typically only occur during a few hours each year.

In the 2012 CASA guidance, the 4.3 m/s threshold was re-defined as a screening "significance" level for stack exit velocities to determine if additional modeling analyses are required (i.e., a level for which impacts on aviation are considered minimal). The 2012 CASA guidance revisions also included a new critical plume velocity criterion of 10.6 m/s, along with a revised plume assessment methodology and new mitigation options if the plume assessment shows a potential hazard to aircraft. The new 10.6 m/s criterion is based on Airservices Australia's "Manual of

3

¹ For the Puente Power Project (CEC Docket#15-AFC-01, TN#213674, 9/15/2016), "CEC staff ... concluded that an average velocity of 5.3 m/s is the appropriate velocity ... [for a plume velocity threshold]." The CEC staff "Plume Background Threshold" attached to the docketed document concludes with "...[CEC] staff will use 10.6 m/s peak vertical plume velocity as the new threshold. The altitude at which a plume would have a peak vertical velocity of 10.6 m/s would be the same altitude at which a plume would have an average vertical velocity of half that, 5.3 m/s."

Aviation Meteorology" which defines severe turbulence as vertical wind gusts in excess of 10.6 m/s, which may cause a momentary "loss of control."

The 10.6 m/s criterion used by CASA is a plume averaged vertical velocity. By definition, the peak vertical velocity in an assumed Gaussian distribution across the plume diameter will be equal to twice the plume-averaged velocity. In recent CEC documents, the 10.6 m/s criterion has been used for peak vertical velocities, representing a plume-average vertical velocity of 5.3 m/s. Thus, a new 5.3 m/s criterion for plume averaged velocities was used in this assessment. While more refined techniques based on The Air Pollution Model (TAPM) are now in favor by CASA, the Spillane methodology, based on calm conditions and a 5.3 or 10.6 m/s vertical velocity, is still a useful tool for assessing potential worst-case SERC impacts on aircraft operations. In addition, use of the Briggs gradual plume rise equations provide a second and more realistic, but still conservative, assessment of SERC impacts in near-calm conditions.

For this report, the plume-averaged vertical velocities were calculated as a function of height under calm conditions using the Spillane methodology. While there are some sections of the plume that may have a vertical velocity higher than the plume-averaged vertical velocity, it has been CASA's experience that these peak vertical velocities do not assess aviation safety risk appropriately. Past discussions between Katestone Environmental, who have used the vertical plume Spillane methodology in various Australian studies, and CASA have concluded that analysis of the average plume height and downwind distance is appropriate for these assessments (i.e., the use of plume-averaged vertical velocities is recommended by CASA).

Spillane Methodology - Calm Wind Screening Scenario

The Spillane methodology is based on worst-case calm wind neutral conditions to assess the average plume vertical velocity as a function of height. The Spillane methodology described next has been used as a conservative methodology throughout Australia for plume assessments. The methodology is based on well-verified laboratory and theoretical treatments of the rise and spread of a buoyant jet, both into a still ambient environment and into a light crosswind. This treatment covers in detail the initial dynamics of the plume as it exits the stack and the entrainment of ambient air into the plume as it rises directly above the stack. In addition to providing clarifications and algebraic solutions to the Spillane methodology, the 2003 Peter Best paper provides additional methodologies that also consider the enhancement of vertical velocities that may occur if the plumes from multiple identical stacks merge and form a higher buoyancy combined plume (also referred to here as the Spillane methodology).

The vertical plume assessment will involve several stages of development. For individual plumes, the stages are:

- (a) In the first stage, very close to the stack exit, the high plume momentum will result in a short section in which the conditions at the center of the plume are relatively unaffected by ambient and plume buoyancy conditions. This jet phase extends from the stack exit to approximately a distance of 6.25 stack diameters (D) above the stack in calm conditions. At the end of this stage, the plume-averaged vertical velocity has decreased to half of the stack exit velocity, with a corresponding increase, or doubling, in effective plume diameter.
- (b) In the second stage, the plume responds to differences between ambient and plume buoyancy conditions, with much cooler and less turbulent ambient air being entrained into the plume from the outside regions of the plume towards the plume centerline. The



momentum and buoyancy of the plume significantly influences plume rise and, subsequently, the dilution of the stack exhaust, to decrease plume vertical velocities. This dilution is very sensitive to ambient wind speed, so the calm wind conditions considered here are extremely conservative.

(c) In the third stage of plume development, plume rise is due entirely to the buoyancy of the plume and continues for some distance until there is an equalization of turbulence conditions within and outside the plume. This final rise is often only achieved at considerable heights/distances from the stack where the effective average vertical velocity is then close to zero. Since there is very little turbulence and near-zero vertical velocity, this stage of plume development is not considered for this type of analysis.

In the second stage of development, the analytical solution of the governing equations under these conditions is given by:

```
a = 0.16(z - z_v)
V = \{ (Va)_o^3 + 0.12F_o[(z - z_v)^2 - (6.25D - z_v)^2] \}^{1/3} / a
```

Where the subscript 'o' refers to parameter values at the stack outlet and the variables are:

- a plume radius (m)
- V average vertical velocity (m/s)
- z height above stack top (m)
- z_v virtual source height (m)
- D stack diameter (m)
- F_o buoyancy flux evaluated at the stack outlet (m^4s^{-3})

These are the two primary equations governing the growth of a single plume in the second stage of development under neutral calm wind conditions. Additional equations governing the first stage of single plume development as well as the interaction of multiple plumes in the second stage of development are discussed in detail in the Best (2003) paper.

For multiple stacks considered using the Spillane methodology, the equations governing the second stage are calculated from the point when the plumes begin to merge until they are fully merged. The plume merging begins at the height where the plume diameters equal the stack separations and the plumes are fully merged at the height where the plume diameters equal 2D(N-1)/2 for three or more stacks or 2D for two stacks. At the fully merged height, the merged plume diameter and velocity is enhanced by the fourth root of the number of stacks. Above the fully merged plume height, the enhanced plume diameter and plume velocities follow the regular equations given for the second stage. Below the fully merged plume height for the merging phase, using the Spillane methodology, plume velocities are linearly interpolated by height from the single plume velocity at the height where the plumes begin to touch to the enhanced plume velocity at the fully merged plume height.

SERC Stack Parameters

Operational characteristics of the CTG, such as emission rate, exit velocity, and exit temperature vary by operating loads and ambient temperatures. The SERC CTGs will be operated over a variety of ambient temperatures and load conditions, as shown in the SERC Application for Certification (AFC) air quality modeling analyses (See AFC Section 5.1). The stack buoyancy flux, a function of stack exit and ambient temperatures and volumetric flow rates, are highest at 100 percent loads



at all temperatures analyzed and are directly related to vertical velocities (i.e., a larger stack buoyancy flux produces larger plume-average vertical velocities, all other factors being equal). Thus, the 100 percent load case was modeled for all ambient temperatures.

For the CTGs, a range of operational characteristics over a variety of ambient temperatures was assessed using the Spillane methodology. This included 100 percent loads for three ambient temperatures: 40°F (cold winter day), 102.7°F (hot summer day), and 65°F (annual average conditions). Again, the CTG operating condition that resulted in the highest calculated buoyancy fluxes at each temperature was used to calculate vertical plume velocities. The stack parameters used in the analysis are summarized in Table 1.

Table 1 Stack Characteristics for Vertical Plume Velocity Analysis (Single Plume)								
Air Quality Modeling Case#	106	103	100					
Ambient Temp (°F)	40	65	102.7					
Stack Height (m)	21.549	21.549	21.549					
Stack Diameter (m)	3.6698	3.6698	3.6698					
Stack Temp (Kelvins)	714.73	721.56	726.31					
Stack Velocity (m/s)	27.680	27.097	26.579					
Buoyancy Flux (m ⁴ /s ³)	559.16	533.45	500.25					

Spillane Results

Vertical plume velocity assessments were made for the worst-case stack condition (100 percent load) for a range of ambient atmospheric temperatures, calm winds and neutral atmospheric conditions. The horizontal separation for the two stacks is 70.42 meters (center-to-center). The Spillane calculation methodology for each case in Table 1 is included as an attachment at the end of this section.

The stack characteristics for the three ambient temperatures are similar for each fuel (stack exit velocity and stack exit temperature). The 40°F case would be expected to produce higher vertical plume velocities as evinced by the higher buoyancy flux, due in part to the larger relative differences between the stack and ambient temperatures. These stack characteristics were used to determine the vertical plume velocities for various elevations above ground level (agl). Table 2 shows the elevations at which stack average vertical velocities equal 5.3 m/s for the single and merged plumes. Table 2 also shows the plume-averaged vertical velocities at 1,000 feet above grade level and the heights for the top of the jet, when the plumes start to touch, and when the plumes are fully merged based on the Spillane methodology.

Table 2 Spillane Ver	tical Plume Veloc	ity Analysis Resu	ults
Air Quality Modeling Case#	106	103	100
Ambient Temp (°F)	40	65	102.7
Top of Jet (ft-agl)	146	146	146
Plumes Touch (ft-agl)	821	820	819
Plumes Merged (ft-agl)	1543	1542	1541
Height for Plume-Averaged Verti	cal Velocity = 5.3	m/s	
Single Plume (ft-agl)	468	451	430
Merged-Plume (ft-agl)	468	451	430
Plume-Averaged Vertical Velocit	y for Height = 1,0	00 ft-agl	



Table 2 Spillane Vertical Plume Velocity Analysis Results							
Single Plume Velocity (m/s)	3.91	3.85	3.77				
Merged Plume Velocity (m/s)	4.15	4.09	4.00				

As expected, heights of the 5.3 m/s vertical velocities and vertical velocities at 1,000 feet above grade level are highest for the 40°F case. The heights of the 5.3 m/s plume-averaged vertical velocities in the single plume Spillane methodology and the multiple plume Spillane methodology are identical for each case. This is because this plume averaged vertical velocity occurs in the single plume phase before the plumes begin to touch. The vertical plume velocities are less than the CEC critical value of 5.3 m/s at 1,000 feet-above grade level for all ambient conditions for individual (single) plumes and for merged plumes. Again, the cases analyzed with the Spillane methodology represent the worst-case conditions of calm winds at all levels of a neutral atmosphere, which also would only occur for a few hours each year.

Brigg's Gradual Plume Rise Methodology and Results – Near-Calm Wind Conditions

The Spillane methodology is based on worst-case calm wind with neutral conditions to assess the plume-averaged vertical velocities as a function of height. In reality, even light wind speeds can dramatically decrease the predicted plume-averaged vertical velocities so the above results are very conservative indications of adverse conditions. The important factor for a given location is the appropriateness of available information for estimating true wind and temperature profiles throughout a typical year. Theoretical calculations based on the Spillane methodology, as shown in the tables above, are likely to overestimate the expected plume-averaged vertical velocities, for the following reasons:

- The wind profile is assumed constant with height with no occurrence of wind-shear
 or increase in wind speeds with height. In reality, there is a considerable variation in
 both wind shear and speed with height, especially in light winds;
- Worst-case scenarios are based on calm winds with near-neutral atmospheric conditions with maximum CTG loading.

Briggs has published equations estimating gradual plume rise under most atmospheric conditions for use in air quality modeling. These equations can be differentiated and combined (Reisman and LeCureux, 2001) to give the following expression of vertical velocity as a function of height:

$$V_{Briggs} = \{ (2/3) (1.6)^{(3/2)} Fo^{(1/2)} u^{(-1/2)} z^{(-1/2)} \}$$

Where the subscript 'o' refers to the parameter values at the stack outlet and the variables are:

- V plume vertical velocity (m/s)
- z height above stack top (m)
- u ambient wind speed (m/s)
- F_o buoyancy flux evaluated at the stack outlet (m^4s^{-3})

A comparison of the results for Briggs' gradual plume rose equations for light wind, near-calm conditions of 0.5 m/s wind speed (the minimum wind speed allowed in most regulatory air quality modeling analyses) to the Spillane methodology are shown in Table 3 below. Included are the heights above grade level of the 5.3 m/s plume-averaged vertical velocity for a single CTG plume and the single plume average vertical velocities at 1,000 feet above grade level.



Table 3 Comparison of Results of Spillane & Briggs Methodologies for a Single Plume								
Air Quality Modeling Case#	106	103	100					
Ambient Temp (°F)	40	65	102.7					
Single Plume Height (ft-agl) for I	Plume-Averaged '	Vertical Velocity	= 5.3 m/s					
Spillane Single Plume	468	451	430					
Briggs' Single Plume	309	298	283					
Single Plume Average Vertical V	elocity (m/s) at H	leight = 1,000 ft-a	gl					
Spillane Single Plume	3.91	3.85	3.77					
Briggs' Single Plume	2.68	2.62	2.54					

As can be seen, even light wind speeds (0.5 m/s) can decrease the predicted plume-averaged vertical velocities. Greater and more realistic wind speeds would produce even smaller vertical velocities using the Briggs gradual plume rise equations. Based on an ambient wind speed of 0.5 m/s, the Briggs' gradual plume rise equations (applicable only to a single plume) predict no plume vertical velocities greater than 5.3 m/s above 309 feet-above grade level. Based on the Spillane methodology of the height at which the plumes begin to merge (see Table 2), this 5.3 m/s height would be well below the height at which the two SERC CTG plumes begin to touch. Thus, no enhancement at the plume heights of the 5.3 m/s Briggs vertical velocities would be expected to occur due to multiple plumes.

Conclusion

Based on the results of the Spillane screening assessments for plume velocities with height, the plume-averaged vertical velocity of 5.3 m/s (peak vertical velocity of 10.6 m/s) is not expected to occur for any of the cases analyzed at elevations above grade level of 500 feet or higher. Based on the Briggs' gradual plume rise equations, the plume-averaged vertical velocity of 5.3 m/s (peak vertical velocity of 10.6 m/s) is not expected to occur at elevations above grade level of about 300 feet or higher. All of these calculations are based on calm (Spillane) or near-calm (Briggs at a 0.5 m/s horizontal wind speed) conditions.

The important factor for a given location is the appropriateness of available information for estimating true wind and temperature profiles throughout a typical year to determine the relative magnitude and frequency of these impacts in navigable airspace. Based on the screening conditions used in this assessment, the worst-case conditions are not expected to occur on a frequent basis. Using actual site meteorological data would provide a more refined approach to assessing the heights of the critical wind speeds, but given the limited vertical extent of significant plume velocities, such an analysis was not deemed to be necessary.

References

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Attachments

Spillane Calculation Summary Sheets Two Turbine Scenarios for 40°F, 65°F, and 102.7°F for Single and Multiple Merged Plumes



	"Aviation Sa	fety and Buo	yant Plumes	," Peter Be	st, et. al.			
	"The Evaluat	ion of Maxin	num Updraft	Speeds for	Calm Con	ditions at V	arious Heights in the Plume	
			-	-			, Australia," Dr. K.T. Spillane	
Ambient Conditions:					-		eutral conditions (dθ/dz=0 or θ _a =	=θ _e)
Ambient Potential Temp θ _a	277.59	Kelvins	40.0				meters/feet	
Plume Exit Conditions:					Gravity g	9.81	m/s ²	
Stack Height h _s	21.549	meters	70.70	feet	λ	1.11		
Stack Diameter D	3.6698	meters	12.04	feet	λο	~1.0		
Stack Velocity V _{exit}	27.680			ft/sec				
Volumetric Flow		cu.m/sec	620,365		πV _{exit} D ² /4			Sect.2/¶1
Stack Potential Temp θ _s		Kelvins	826.8		··· exit— · ·			
Initial Stack Buoyancy Flux F ₀	559.16				aV _{avit} D ² (1-	$\theta_a/\theta_c)/4 = V$	ol.Flow(g/ π)(1- θ_a/θ_s)	Sect.2/¶1
Plume Buoyancy Flux F		m ⁴ /s ³					',θ _n at plume height (see below)	0000.27 1
		111 75			3 (ар/, -	,-p p	
Conditions at End (Top) of Jet Phase:								
Height above Stack z _{iet}	22 936	meters*	75.3	feet*	z = 6.25[) meters*=	meters above stack top	Sect.3/¶1
Height above Ground z _{iet} +h _s		meters	145.9		Ljet 0.201	,	motore above etack top	"
Vertical Velocity V _{jet}	13.840			ft/sec	V _{iot} = 0.5V	exit = Vexit/2		
Plume Top-Hat Diameter 2a _{iet}		meters	24.1		2a _{iet} = 2D	exit • exit-	Conservation of momentum	
riamo ropinal Biamotor Zajel	7.010	motoro	2	1001	Zajet ZB		Concortation of monoritain	
Spillane Methodology - Analytical Solutions	for Calm Con	ditions for Pl	lume Heiahts	s above Jet	Phase			
Single Plume-averaged Vertical Velocity						given hv e	quations below:	
Plume Top-Hat Radius a		olutions in T					•	Sect.2/Eq.6
Virtual Source Height z _v		meters*		feet*			ers*=meters above stack top	Sect.2/Eq.6
Height above Ground z _v +h _s		meters	99.1		5.20D[1-(0)	er os, j, met	where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2} =$	
Vertical Velocity V		olutions in T		icci	((\/a) ³ ± 0	12F. [/z. =	$(\theta_a/\theta_s)^2 = (\theta_e/\theta_s)^2$ $(0.25D-z_v)^2$	0.6232 Sect.2.1(6
Product (Va) _o	31.653		TOIL DEIOM		$V_{\text{exit}}D/2(\theta_{\text{e}})$		// (0.20D-2y)]]· · / a	JEUL. Z. 1(D
Floudti (Va) ₀	31.053	111 /5			▼ exitU/∠(Ue	os)		
Solve for plume-averaged vertical velo	city at hoight	1,000.0	foot	204.0	meter at	ove ground (7'+h)	
	283.251		929.3		meters abo	ove ground (Z +11 _S)	
Gives the following Height above Stack z'					2=1-2*0.46	(-! -)		Sect.2/Eq.6
Plume Top-Hat Diameter 2a'		meters	288.3		2a'=2*0.16	,		Sect.2/Eq.6
Vertical Velocity V	3.912	m/s	12.83	ft/sec	v={(va) _o -+	0.12F ₀ [(Z-Z	v) ² -(6.25D-z _v) ²]} ^(1/3) /(2a'/2)	Sect.2/Eq.6
Calva for Unions of CASC original variation	valacity V		()					
Solve for Height of CASC critical vertical			m/s plume-a			-		
Find Height above Stack z _{crit}	121.016		397.0				ultaneously in both eqs. (i.e., Va	
Height above Ground z _{crit} +h _s	142.565	meters	467.7	teet	tor V=4.3 r		e cubic equation ax3+bx2+cx+d	
based on Brig							0, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)=	-110.03
Find Height above Stack z _{crit}		meters	237.8	teet	an	$d d=[0.12F_c]$	$(6.25D-z_v)^2-(Va)_o^3]/(4.3^30.16^3)=$	-295
Height above Ground z _{crit} +h _s								
- 3	94.025	meters	308.5	feet			http://www.1728.	
. O	94.025	meters	308.5	feet		g	ives the real solution x = z-zv =	112.37
							ives the real solution x = z-zv = or z(m) =	112.37 121.0
Table of Plume Top-Hat Diameters (2a) and F	Plume-averag	ed Vertical \	Velocities sta	arting at en		ase:	ives the real solution $x = z - zv = $ or $z(m) = $ z(ft) =	112.37 121.0 397
able of Plume Top-Hat Diameters (2a) and F Height (feet)	Plume-averag (meters)	ed Vertical \	Velocities sta	rting at en		ase: Brigg's	ives the real solution $x = z - zv = 0$ or $z(m) = 0$ z(ft) = 0 $V_{Baggle} = (2/3) \times 1.6^{(3/2)} \times F^{(1/2)} \times u^{(1/2)}$	112.37 121.0 397
able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground	Plume-averag (meters) above stack	ed Vertical \ Plume Radius(m)	Velocities sta Vert. Vel(m/s)	rting at en		ase: Brigg's Grad'PR	ives the real solution $x = z \cdot zv =$ $or \ z(m) =$ $z(ft) =$ $V_{\text{BeggS}} = (2/3) \times 1.6^{(3/2)} \times F^{(1/2)} \times u^{(1/2)},$ $0.50 \ \text{m/s windspeed}$	112.37 121.0 397
able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9	Plume-averag (meters) above stack 22.92	ed Vertical \ Plume Radius(m) 3.670	Velocities sta Vert. Vel(m/s) 13.84	erting at en Plume Temp(K)		ase: Brigg's Grad'PR	ives the real solution $x = z \cdot zv =$ $or \ z(m) =$ $z(ft) =$ $V_{\text{Beggib}} = (2/3) \times 1.6^{(3/2)} \times F^{(1/2)} \times u^{(1/2)},$ $0.50 \ \text{m/s windspeed}$ Spillane Equations:	112.37 121.0 397 × z ^(-1/2)
Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0	Plume-averag (meters) above stack 22.92 39.41	ed Vertical \ Plume Radius(m) 3.670 4.923	Velocities sta Vert. Vel(m/s) 13.84	Plume Temp(K) 337.75		ase: Brigg's Grad'PR 9.42 7.19	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$ $Z(ff) = 0$ Z	112.37 121.0 397 × z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0	Plume-averag (meters) above stack 22.92 39.41 69.89	ed Vertical V Plume Radius(m) 3.670 4.923 9.800	Velocities sta Vert. Vel(m/s) 13.84 8.81 6.59	Plume Temp(K) 337.75 297.87		ase: Brigg's Grad'PR 9.42 7.19 5.40	$\label{eq:power_control} \begin{split} &\text{ives the real solution x} = z - z v = \\ &\qquad \qquad $	112.37 121.0 397 x z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37	ed Vertical \ Plume Radius(m) 3.670 4.923 9.800 14.677	Velocities sta Vert. Vel(m/s) 13.84 8.81 6.59 5.69	Plume Temp(K) 337.75 297.87 288.07		ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50	$\begin{aligned} &\text{ves the real solution x} = z - z v = \\ &\text{or } z(m) = \\ &z(ft) = \\ &V_{Bnggh} = (2/3) \times 1.6^{(3/2)} \times F^{(1/2)} \times U^{(1/2)}, \\ &0.50 \text{ m/s windspeed} \end{aligned}$ $&\text{Spillane Equations:} \\ &V_{pluso} = \{(Va)_b^3 \cdot 40.12F_a((z-z_v)^2 \cdot (6.25Da = 0.16(z-z_v) + (1/2)^2 \cdot (1/2)^2 $	112.37 121.0 397 x z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85	ed Vertical \ Plume Radius(m) 3.670 4.923 9.800 14.677 19.553	Velocities sta Vert. Vel(m/s) 13.84 8.81 6.59 5.69 5.15	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11		ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94	ives the real solution $x = z - z v = 0$ or $z(m) = z(ft) = z(ft) = 0.50$ $V_{8nggh} = (2/3) \times 1.6^{(3/2)} \times F^{(1/2)} \times V^{(1/2)} \times 0.50$ W_{10} in W_{10} i	112.37 121.0 39' < z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37	ed Vertical \ Plume Radius(m) 3.670 4.923 9.800 14.677	Velocities sta Vert. Vel(m/s) 13.84 8.81 6.59 5.69	Plume Temp(K) 337.75 297.87 288.07		ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50	ives the real solution $x = z - z v = 0$ or $z(m) = z(ft) = z(ft) = 0.50$ $V_{8nggh} = (2/3) \times 1.6^{(3/2)} \times F^{(1/2)} \times V^{(1/2)} \times 0.50$ W_{10} in W_{10} i	112.37 121.0 39' < z ^(-1/2)
Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85	ed Vertical \ Plume Radius(m) 3.670 4.923 9.800 14.677 19.553	Velocities sta Vert. Vel(m/s) 13.84 8.81 6.59 5.69 5.15	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10		ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94	ives the real solution $x = z-zv = 0$ or $z(m) = z(ft) = z(ft) = z(ft) = 0.50m/s e^{-(2/3)} x f^{-(2/3)} x f^{-(2/3)} x f^{-(2/3)} x f^{-(2/3)} x f^{-(2/3)} x f^{-(2/3)} e^{-(2/3)} x f^{-(2/3)} e^{-(2/3)} e^{$	112.37 121.0 39' < z ^(-1/2)
Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430	Velocities state Vert. Vel(m/s) 13.84 8.81 6.59 5.69 5.15	arting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92		ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.55	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$ (ff) = $\sqrt{8} \log_2 x + (2/3) x + (3/2) x + (1/2) x + ($	112.37 121.0 39' < z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307	Velocities sta Vert. Vel(m/s) 13.84 8.81 6.59 5.69 5.15 4.77 4.48	arting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92		ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.55 3.26	ives the real solution x = z-zv = or z(m) = z(ft) = z(ft) = V _{Briggs} = (2/3) x $1.6^{0.22}$ x $1^{1/22}$ x	112.37 121.0 39' < z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81	ed Vertical N Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184	Velocities sta Vert. Vel(m/s) 13.84 8.81 6.59 5.69 5.15 4.77 4.48 4.26	Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.55 3.26 3.03	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0.50$ m/s windspeed Spillane Equations: $V_{\text{plums}} = (2/3) \times 1.6^{(9/2)} \times f^{(1/2)} \times u^{(1/2)} \cdot u^{(1/2)} \cdot$	112.37 121.0 39' < z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208	Velocities state Vert. Vel(m/s) 13.84 8.81 6.59 5.69 5.15 4.77 4.26 4.21	Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.55 3.26 3.03 2.98	ives the real solution $x = z - z v = 0$ or $z(m) = z(ft) = 0.50$ m/s windspeed Spillane Equations: $V_{\text{plume}} = ((Va)_3^{3} \times 1.6^{0.20}) \times f^{(V2)} \times v^{(V3)} $	112.37 121.0 39' < z ^(-1/2)
Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69	ed Vertical Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208	Velocities state Vert. Vel(m/s) 13.84 8.84 6.59 5.69 5.15 4.77 4.48 4.226 4.221 4.07	Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.944 3.55 3.26 3.03 2.98 2.84	ives the real solution $x = z - z v = 0$ or $z(m) = z(ft) = z(ft) = 0.50$ m/s windspeed Spillane Equations: $V_{\text{pluse}} = \{(2/3) \times 1.6^{(3/2)} \times F^{(1/2)} \times U^{(1/2)}, \\ 0.50 \text{ m/s windspeed}$ Spillane Equations: $V_{\text{pluse}} = \{(V_0)_a^3 \cdot 40.12F_a((z-z_s)^2 \cdot (6.25D - z_s)^2) \cdot (6.25D - z_s) \cdot $	112.37 121.0 39' < z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 Begin Merging (touch) = 821.0 900.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25	ed Vertical I Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937	Velocities state Vert. Vel(m/s) 13.84 8.84 6.59 5.69 5.15 4.77 4.48 4.226 4.221 4.07	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.69 279.29	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.555 3.26 3.03 2.98 2.84	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$. Wangs = $(2/3) \times 1.6^{(3/2)} \times 1^{(1/2)} \times 0^{(1/2)} \times 0.50 \text{ m/s}$ windspeed Spillane Equations: $V_{\text{plum}} = \{(Va)_3^3 + 0.12F_3[(z-z)^3 - (6.25D a = 0.16(z-z_v) = 0.16(z-z_v) = 0.16(z-z_v) = 0.16(z-z_v) = 0.16(z-z_v)$	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1000.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814	Velocities state Vert. Velm.5 13.64 8.81 6.59 5.15 4.777 4.48 4.26 4.27 3.91 3.78	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.29 279.66 279.29 279.02	d of jet ph	ase: Brigg's Grad'PR 9.42 7.199 5.40 4.50 3.94 4.50 3.03 2.98 2.84 2.68 2.55	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$ (ff) = $\sqrt{8} \log_3 s = (2/3) \times 1.6^{(3/2)} \times 1^{f(2)} \times u^{f(2)} \times u^{$	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 1000.0 1100.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691	Velocities state Vert. Velm/s) 13.84 8.81 6.59 5.69 5.15 4.777 4.48 4.26 4.21 4.07 3.91 3.783 3.66 3.55	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 279.02 278.81 278.64	d of jet ph	ase: Brigg's Grad'PR 9.42 7.199 5.40 4.50 3.94 3.55 3.26 3.03 2.98 2.84 2.68 2.555 2.43	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$. Variety $z(ff) = z = (2/3) \times 1.6^{(2/3)} \times 1^{(1/2)} \times 1^{(1/$	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1100.0 1200.0 1300.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69	ed Vertical 1 Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.445	Velocities state Vert. Velm/s) 13.84 8.81 6.59 5.69 5.15 4.77 4.48 4.26 4.21 4.07 3.91 3.78 3.666 3.555 3.46	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 279.81 278.64 278.64	d of jet ph	ase: Brigg's Grad'PR 9.422 7.19 5.40 4.50 3.94 3.55 3.262 3.03 2.98 2.84 2.68 2.43 2.33 2.23	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0.50$ m/s windspeed Spillane Equations: $V_{\text{plum}} = (2/3) \times 1.6^{(3/2)} \times f^{(1/2)} \times t^{(1/2)} \times $	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 1000.0 1100.0 1200.0 1300.0 1400.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17	ed Vertical 1 Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.5686 63.445 68.321	Velocities state Vert. Vel(m/s) 13.84 8.81 6.59 5.69 5.15 4.77 4.478 4.426 4.21 4.07 3.91 3.78 3.66 3.555 3.46	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 279.81 278.81 278.84	d of jet ph	ase: Brigg's Grad PR 9.42 7.19 5.40 4.50 3.94 3.55 3.26 3.03 2.98 2.84 2.68 2.55 2.43 2.33 2.24 2.16	ives the real solution $x = z - z v = 0$ or $z(m) = z(ft) = 0.50$ m/s windspeed Spillane Equations: $V_{\text{plum}} = (2/3) \times 1.6^{(3/2)} \times f^{(1/2)} \times u^{(1/2)} \times $	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 1000.0 1100.0 1200.0 1400.0 1400.0 1500.0 End Merging (full/mp) = 1543.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 263.25 313.73 344.21 374.69 405.17 435.65	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.445 68.321 70.418	Velocities state Vert. Vel(m/s) 13.84 8.81 6.59 5.69 5.161 4.77 4.48 4.26 4.21 3.91 3.78 3.66 3.55 3.444 3.37	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.62 279.62 279.62 278.81 278.64 278.51 278.64	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.555 3.26 3.03 2.98 2.84 2.88 2.255 2.43 2.33 2.24 2.166 2.13	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$ ($z(ff) = z = 0$). So $z(ff) = z = 0$ or $z(ff) = z = 0$. So $z = z = 0$ or $z = 0$ or $z = 0$. Spillane Equations: $v_{pluno} = f(va)_0^3 + 0.12F_0([c - z_v)^3 - (6.25D a = 0.16(z - z_v)) = 0$, $z = 0$. $z = $	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1100.0 1200.0 1300.0 1400.0 End Merging (full/mp) = 1543.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 263.25 313.73 344.21 374.69 405.17 435.65	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.445 66.325 70.418	Velocities state Vert. Velm(s) 13.64 8.81 6.59 5.69 5.15 4.777 4.48 4.22 4.21 4.07 3.91 3.78 3.66 3.55 3.37 3.34 3.30	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.62 279.62 279.62 279.62 279.62 279.62 279.64 278.81 278.84 278.85 278.84 278.87 278.83	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.555 3.26 3.03 2.98 2.84 2.68 2.55 2.43 2.33 2.24 2.161 2.13 2.09	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$ (ff) = $z(ff) = z = 0.50$ where $z(ff) = z = 0.50$ we windspeed Spillane Equations: $v_{plume} = (Va)_0^3 + 0.12F_0([z-z_v)^2 - (6.25D a = 0.16(z-z_v)) = 0.16(z-z_v)$ $\theta_p = \theta_a (1 + (1 - (\theta_e/\theta_a))^a (V_{ext}D^2/4V)$	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 600.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1543.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.76 466.13	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 22.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.445 68.321 70.418 73.198	Velocities state Vert. Velm/s) 13.84 8.81 6.59 5.69 5.15 4.777 4.48 4.26 4.21 4.07 3.78 3.66 3.55 3.46 3.37 3.343 3.30	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 278.81 278.64 278.51 278.41 278.37 278.32	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.55 3.26 3.03 2.98 2.84 2.68 2.55 2.43 2.33 2.24 2.16 2.13 2.09	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$ (ff) = $z(ff) = 0.50$ m/s windspeed Spillane Equations: $v_{plume} = (Va)_0^3 - 0.12F_0([z-z_v)^2 - (6.25D = 0.16(z-z_v)) = 0.99_0(1+(1-(\theta_0/\theta_0))^*(V_{ext}D^2/(4V_0)^2 - (1-(\theta_0/\theta_0))^*(V_{ext}D^2/(4V_0)^2 - (1-(\theta_0/\theta_0))^*(V_0) = 0.00$	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1100.0 1200.0 1300.0 1400.0 End Merging (full/mp) = 1543.0 1600.0 1700.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.76 466.13 496.61 527.09	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.533 24.430 29.307 34.184 35.208 39.061 43.397 58.568 63.445 68.321 70.418 73.198 78.075 82.952	Velocities state Vert. Velm/s) 13.84 8.81 6.59 5.69 5.15 4.77 4.48 4.26 4.21 4.07 3.91 3.78 3.66 3.55 3.44 3.37 3.34 3.30 3.32 3.16	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 278.81 278.64 278.51 278.41 278.37 278.32 278.24 278.18	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 4.50 3.26 3.03 2.98 2.84 2.68 2.55 2.43 2.33 2.24 2.16 2.13 2.09 2.02 1.97	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$. Variety $z(ff) = z = (2/3) \times 1.6^{(3/2)} \times 1^{(1/2)} \times 1^{(1/$	112.37 121.0 39' < z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1000.0 1200.0 1200.0 1300.0 End Merging (full/mp) = 1543.0 End Merging (full/mp) = 1543.0 1700.0 1800.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.76 466.13 496.61 527.09 557.57	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.445 68.321 70.418 73.198 73.198 78.075 82.952 87.829	Velocities state Vert. Vel(m/s) 13.84 8.81 6.59 5.69 5.15 4.77 4.48 4.26 4.21 4.07 3.91 3.78 3.36 3.37 3.34 3.30 3.32 3.16 3.10	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 278.81 278.64 278.51 278.41 278.37 278.32 278.24 278.18	d of jet ph	ase: Brigg's Grad'PR 9.442 7.19 5.40 4.50 3.94 3.55 3.226 3.03 2.98 2.84 2.68 2.55 2.43 2.33 2.24 2.16 2.13 2.09 2.02 2.02 1.97	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0.50$ m/s windspeed Spillane Equations: $V_{\text{plum}} = (Va)_0^3 + 0.12F_0((z-z_0)^2 \cdot (6.25)$ $a = 0.16(z-z_0)$ $\theta_p = \theta_0 (1 + (1 - (\theta_0/\theta_0))^* (V_{\text{ext}}D^2/(4V_{\text{ext}})^2 \cdot (6.25))$	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1100.0 1200.0 1200.0 1400.0 1500.0 End Merging (full/mp) = 1543.0 1600.0 1800.0 1800.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.76 466.13 496.61 527.09 557.57 588.05	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.445 63.435 70.418 73.198 78.075 82.952 87.829	Velocities state Vert. Velmins) 13.84 8.81 6.59 5.69 5.15 4.77 4.48 4.26 4.27 3.91 3.78 3.66 3.55 3.44 3.37 3.34 3.30 3.23 3.16 3.100 3.05	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.69 279.02 278.81 278.64 278.81 278.37 278.32 278.24 278.13 278.08	d of jet ph	ase: Brigg's Grad PR 9.42 7.19 5.40 4.50 3.94 3.55 3.26 3.03 2.98 2.84 2.68 2.55 2.43 2.16 2.13 2.09 1.97 1.91 1.86	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$ $z(ff) = 0$ z	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1100.0 1200.0 1300.0 End Merging (full/mp) = 1543.0 1600.0 1700.0 1800.0 1700.0 2000.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.76 466.13 496.61 527.09 557.57 588.05 649.01	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.432 70.418 73.198 78.075 82.925 87.829 92.705	Velocities state Vert. Velm(s) 13.64 8.81 6.59 5.69 5.15 4.77 4.48 4.26 4.21 3.39 3.366 3.55 3.37 3.34 3.30 3.23 3.16 3.10 3.05	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 279.02 278.81 278.64 278.51 278.44 278.37 278.32 278.24 278.18 278.18 278.18	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.555 3.26 3.03 2.98 2.84 2.68 2.55 2.43 2.33 2.24 2.16 2.13 2.09 1.97 1.91 1.86 1.77	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$ (ff) = $z(ff) = 0$ Variety $z = (2/3) \times 1.6^{(3/2)} \times 1^{(1/2)} \times 1^{(1/2)$	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1000.0 1100.0 1200.0 1300.0 End Merging (full/mp) = 1543.0 1600.0 1700.0 1800.0 1900.0 2000.0 2200.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.76 466.13 496.61 527.09 557.57 588.05 649.01 709.97	ed Vertical V Plume Radlus(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.445 67.418 73.198 78.075 82.952 87.829 92.7055 102.459	Velocities state Vert. Velm/s) 13.84 8.81 6.59 5.69 5.15 4.777 4.48 4.26 4.21 4.07 3.97 3.343 3.30 3.35 3.366 3.355 3.46 3.310 3.30 3.23 3.16 3.10 3.05 2.95	riting at en Plume Temp(K) 337.75 297.87 288.07 284.10 280.92 280.17 280.05 279.66 279.29 278.81 278.64 278.51 278.32 278.24 278.13 278.05	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.55 3.66 3.03 2.98 2.84 2.68 2.55 2.43 2.33 2.24 2.16 2.13 2.09 2.02 1.97 1.91 1.86	ives the real solution x = z-zv = or z(m) = z(ft) = z(ft) = V _{Briggs} = (2/3) x 1.6 ^{0/20} x E ^{T/20} x U ^{1/20} x, U ^{1/20}	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1100.0 1200.0 1300.0 1400.0 End Merging (full/mp) = 1543.0 1600.0 1700.0 1800.0 1900.0 2000.0 2200.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.76 466.13 496.61 527.09 557.57 588.05 649.01 709.97 770.93	ed Vertical N Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.445 68.321 70.418 73.198 78.075 82.952 87.829 92.705 102.499 112.213	Velocities state Vert. Velm/s) 13.84 8.81 6.59 5.69 5.15 4.777 4.48 4.26 4.21 4.07 3.91 3.78 3.66 3.55 3.46 3.37 3.34 3.30 3.23 3.16 3.10 3.05 2.95 2.86	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 278.81 278.64 278.51 278.32 278.24 278.13 278.08 278.01 277.95	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.55 3.26 3.03 2.98 2.84 2.68 2.55 2.43 2.33 2.24 2.16 2.19 2.00 1.97 1.91 1.86 1.777 1.69	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$ (ff) = $z(ff) = 0.50$ m/s windspeed Spillane Equations: $v_{plume} = (v(va)_a^{3} + 0.12F_a([z-z_a)^{2} - (6.25)a = 0.16(z-z_v)$ $\theta_p = \theta_a (1 + (1 - (\theta_0/\theta_a))^* (V_{ext}D^2/4V)$	112.37 121.0 39' < z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1000.0 1100.0 1200.0 1400.0 5500.0 End Merging (full/mp) = 1543.0 1600.0 1700.0 1800.0 2000.0 2200.0 2400.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17 435.65 446.76 1527.09 557.57 588.05 649.01 709.97 770.93 831.89	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.533 24.430 29.307 34.184 35.208 39.061 43.971 58.568 63.445 68.321 70.418 73.198 78.075 82.952 87.829 92.705 102.459 112.213 121.966 131.720	Velocities state Vert. Velm/s) 13.84 8.81 6.59 5.69 5.15 4.77 4.48 4.26 4.21 4.07 3.91 3.366 3.55 3.46 3.37 3.34 3.30 3.23 3.16 3.10 3.05 2.95 2.886 2.78	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 278.81 278.64 278.51 278.41 278.37 278.82 278.24 278.18 278.13 278.08 277.90 277.86	d of jet ph	ase: Brigg's Grad'PR 9.422 7.19 5.40 4.50 3.94 4.50 3.03 2.98 2.84 2.68 2.33 2.24 2.16 2.13 2.09 2.02 1.97 1.91 1.86 1.63 1.63	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$. Variety $z(ff) = z = (2/3) \times 1.6^{(3/2)} \times 1^{(1/2)} \times 1^{(1/$	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 821.0 900.0 1100.0 1200.0 1200.0 1400.0 1500.0 End Merging (full/mp) = 1543.0 1600.0 1700.0 1800.0 2000.0 2200.0 2200.0 2600.0 2800.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 263.25 313.73 344.21 374.69 466.13 496.61 527.09 557.57 588.05 649.01 709.97 770.93 831.89 892.85	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.445 68.321 70.418 73.198 78.075 82.952 87.829 92.705 102.459 112.13 121.966 131.720 141.473	Velocities state Vert. Velmins) 13.84 8.81 6.59 5.69 5.15 4.77 4.48 4.26 4.27 3.91 3.78 3.66 3.55 3.44 3.37 3.34 3.30 3.23 3.16 3.10 3.05 2.95 2.86 2.71	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.99 279.02 278.81 278.64 278.51 278.41 278.13 278.08 278.01 277.95 277.95 277.86	d of jet ph	ase: Brigg's Grad'PR 9.442 7.19 5.40 4.50 3.94 3.55 3.26 3.03 2.98 2.84 2.68 2.55 2.43 2.33 2.24 2.16 2.13 2.09 2.02 1.97 1.91 1.86 1.77 1.69 1.63 1.56 1.51	ives the real solution $x = z - z v = 0$ or $z(m) = z(ff) = 0$ $z(ff) = 0$ z	112.37 121.0 39' < z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 800.0 800.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1543.0 1600.0 1700.0 1800.0 2000.0 2000.0 2400.0 2800.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.76 466.13 496.61 527.09 557.57 588.05 649.01 709.97 770.93 831.89 892.85 1045.25	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.432 70.418 73.198 78.075 82.952 87.829 92.705 102.459 112.213 121.966 131.7620 141.473 165.857	Velocities state Vert. Velm(s) 13.84 8.81 6.59 5.69 5.155 4.77 4.48 4.26 4.21 4.07 3.91 3.78 3.66 3.55 3.37 3.34 3.30 3.23 3.16 3.05 2.95 2.86 2.78 2.71 2.655	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 279.02 278.81 278.64 278.32 278.24 278.18 278.32 278.24 278.18 278.33 277.90 277.96 277.96	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 4.50 3.26 8.255 2.43 2.33 2.24 2.16 2.13 2.09 2.02 1.97 1.99 1.63 1.556 1.551	ives the real solution x = z-zv = or z(m) = z(ft) = VBargs = (2/3) x 1.6 ^(3/2) x F ^(1/2) x u ^(1/2) ; 0.50 m/s windspeed Spillane Equations: Vplume="{(Va) ₀ ³ +0.12F ₀ {(z-z ₀) ² -(6.25D a = 0.16(z-z ₀)} θ _p =θ ₈ (1+(1-(θ _e /θ ₈))*(V _{extl} D ² /(4V	112.37 121.0 397 x z ^(-1/2)
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 600.0 700.0 800.0 800.0 8egin Merging (touch) = 821.0 900.0 1100.0 1200.0 1300.0 1400.0 End Merging (full/mp) = 1543.0 1600.0 1700.0 2000.0 2000.0 2400.0 2800.0 3000.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.76 466.13 496.61 527.09 575.75 588.05 649.01 709.97 770.93 831.89 892.85 1045.25 1197.65	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.445 63.421 70.418 73.198 78.075 82.952 87.829 92.705 102.459 112.213 121.966 131.720 141.473 165.857	Velocities state Vert. Velm/s) 13.84 8.81 6.59 5.69 5.15 4.777 4.48 4.26 4.27 4.07 3.91 3.78 3.66 3.55 3.46 3.35 3.43 3.30 3.23 3.16 3.05 2.86 2.78 2.71 2.66 2.51	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 279.02 278.81 278.84 278.51 278.32 278.24 278.18 278.18 277.95 277.96 277.86 277.78	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 3.555 3.26 3.03 2.98 2.84 2.68 2.555 2.43 2.33 2.24 2.16 2.13 2.09 1.97 1.91 1.689 1.77 1.69 1.63 1.56 1.51	ives the real solution x = z-zv = or z(m) = z(ft) = z(ft) = V _{Briggs} = (2/3) x 1.6° ^{2/2} x E ^{1/2/2} x U ^{1/2/2} ; 0.50 m/s windspeed Spillane Equations: V _{plume} =((Va) _o ³ 9.0.12F _o (z-z _o) ² -(6.25D a = 0.16(z-z _o)) = 0.16(z-z _o) = 0.16(z-z _o)	112.37 121.0 39 c z ^(-1/2) z _v) ²]} ^{1/3} / a
Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 800.0 Begin Merging (touch) = 821.0 900.0 1100.0 1200.0 1300.0 End Merging (full/mp) = 1543.0 1600.0 1700.0 1800.0 2000.0 2200.0 2400.0 2800.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.69 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.76 466.13 496.61 527.09 557.57 588.05 649.01 709.97 770.93 831.89 892.85 1045.25	ed Vertical V Plume Radius(m) 3.670 4.923 9.800 14.677 19.553 24.430 29.307 34.184 35.208 39.061 43.937 48.814 53.691 58.568 63.445 63.421 70.418 73.198 78.075 82.952 87.829 92.705 102.459 112.213 121.966 131.720 141.473 165.857	Velocities state Vert. Velm/s) 13.84 8.81 6.59 5.69 5.15 4.777 4.48 4.26 4.27 4.07 3.91 3.78 3.66 3.55 3.46 3.35 3.43 3.30 3.23 3.16 3.05 2.86 2.78 2.71 2.66 2.51	riting at en Plume Temp(K) 337.75 297.87 288.07 284.11 282.10 280.92 280.17 280.05 279.66 279.29 279.02 278.81 278.84 278.51 278.32 278.24 278.18 278.18 277.95 277.96 277.86 277.78	d of jet ph	ase: Brigg's Grad'PR 9.42 7.19 5.40 4.50 3.94 4.50 3.26 8.255 2.43 2.33 2.24 2.16 2.13 2.09 2.02 1.97 1.99 1.63 1.556 1.551	ives the real solution x = z-zv = or z(m) = z(ft) = z(ft) = V _{Briggs} = (2/3) x 1.6° ^{2/2} x E ^{1/2/2} x U ^{1/2/2} ; 0.50 m/s windspeed Spillane Equations: V _{plume} =((Va) _o ³ 9.0.12F _o (z-z _o) ² -(6.25D a = 0.16(z-z _o)) = 0.16(z-z _o) = 0.16(z-z _o)	112.37 121.0 39' < z ^(-1/2)



		-	ioyant Plumes			ditions - · ·	/arious Heights in the Merg	od
	THE EVALUA						ueensland, Australia," Dr. F	
Ambient Conditions:		r ramo mon					eutral conditions (d0/dz=0 or	
Ambient Potential Temp θ_a	277.59	Kelvins	40.0	°F		0.3048	meters/feet	
Plume Exit Conditions:					Gravity g		m/s ²	
Stack Height h _s Stack Diameter D		meters meters	70.7	feet	λ	1.11 ~1.0		
Number of Stacks N	3.0090		12.0	leet			e plume treatment in Peter Be	st Paper:
Average Adjacent Stack Separation d	_	meters	231.04	feet			sed by N ^{0.25} at the height when	
Stack Velocity V _{exit}	27.68			ft/sec			low ht, single merged stack a	
Volumetric Flow	292.78	cu.m/sec	620,365	ACFM	πV _{exit} D ² /4			Sect.2/¶1
Stack Potential Temp θ _s		Kelvins	827	°F				
Initial Stack Buoyancy Flux Fo	559.16				-		ol.Flow(g/π)(1-θ _a /θ _s)	Sect.2/¶1
Plume Buoyancy Flux F Conditions at End (Top) of Jet Phase:		m4/s3					θ _p at plume height (see belo	
Height above Stack z _{jet}		meters* meters	75.3 145.9	feet*	$z_{jet} = 6.25E$), meters*=	meters above stack top	Sect.3/¶1
Height above Ground z _{jet} +h _s Vertical Velocity V _{jet}	13.840			ft/sec	V _{jet} = 0.5V _e	= V/2		
Plume Top-Hat Diameter 2a _{jet}		meters		feet	2a _{jet} = 2D	exit exit	Conservation of momentum	
					1			
Spillane Methodology - Analytical Solutions t								
Single Plume-averaged Vertical Velocity								
Single Plume Values: Plume Top-Hat Radius a			e Merging On				r increase with height	Sect.2/Eq.6
Virtual Source Height z _v Height above Ground z _v +h _s		meters*		feet*	z _v = 6.25D	[1-(θ _e /θ _s) ^{1/2}]	, meters*=meters above stack top where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2}$ =	
Single Plume Values: Vertical Velocity V		meters ed in Plume	99.1 Merging On		{(Va) ₂ 3 + 0	12F。[/7-7	where $(\theta_a/\theta_s)^{-1} = (\theta_e/\theta_s)^{-1} = (0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 $	0.6232 Sect.2.1(6)
Product (Va) _o	31.653		. gy Ull		V _{exit} (D/2)(θ		., (EV/ IJ / G	
	21.000				CAR(-12)(O	,		
Plume Merging - Based on Single Plume Cal	culations wh	ere:						Sect.3/¶3
Begin Merging Plume Top-Hat Diameter 2atouch	70.420	meters	231.0	feet	2a _{touch} =d, (or a _{touch} =d/	2)	
Height above Stack z _{touch}	228.705		750.3		z _{touch} = z _v +	·d/(2*0.16),	meters*=meters above stack	top
Height above Ground z _{touch} +h _s	250.254		821.0			-, 3	F F / 12 /2 apr - 2-/4/21	
Vertical Velocity V _{touch} Total Merging Plume Top-Hat Diameter 2a _{full}	4.214 140.840		13.8 462.1	ft/sec			F ₀ [(z-z _v) ² - (6.25D-z _v) ²]} ^(1/3)	
Height above Stack z _{full}	448.767		1472.3				meters*=meters above stack	
Height above Ground z _{full} +h _s	470.316		1543.0		Zfull = Zv+Z	u/(2 0.10),	illeters =illeters above stack	Юр
Vertical Velocity V _{full}	3.340			ft/sec	V _{full} = {(Va) ₀ 3 + 0.12F ₀	[(z _{full} -z _v) ² - (6.25D-z _v) ²]} ^(1/3)	/ a _{full}
Product (V ³ a) _{full}	2,625	m4/s3			1			
Conditions at End (Top) of Merging Phase - D	efine new valu	es for V _{full} a	and a _{full} in Merg	ed Plume o	calculations:			
Merged Plume Values: Plume Diameter 2a	S	olutions in	Table Below				z _{full})), or linear increase with I	neight
Revised Merged Plume Radius a _m		meters	274.8				here Total Merging Occurs	
Revised Merged Plume Velocity V _m	3.972			ft/sec			where Total Merging Occurs	
Revised Virtual Source Height z _{full} Revised Vertical Velocity V		meters*	1472.3 Tables Below	teet*			ere Total Merging Occurs (sheights above total merging ele	
Revised Vertical Velocity V	3	olutions in	Tables below				eignis above total merging ei z-z _{touch})/(z _{full} -z _{touch})	evation
Multiple Plume Calculations					• • touch · (· m · touch) (for heights below total mergi	ng elevation
Solve for plume-averaged vertical veloc	ity at height	1,000.0	feet	304.8	meters abo	ve ground (z+h _s)	
Gives the following Height above Stack z	283.251	meters*	929.3	feet*	LESS THA	N TOP OF	MERGING PHASE-INTERPO	LATE
Plume Top-Hat Radius a		meters	#N/A		a=a _m +0.16			
Vertical Velocity V	4.154	m/s	13.63	ft/sec	V={N(V3a) _f	,		
							z'-z _{touch})/(z _{full} -z _{touch}) if z _{touch} < s if z <z<sub>touch</z<sub>	Z <z<sub>full</z<sub>
Solve for Height of CASC critical vertical	velocity V	5 30	m/s		BEFORE T		II Z Ztouch	
Find Height above Stack z _{crit}	SINGLE		SINGLE	feet			/(V _{crit}) ³]-a _m }/0.16 if V_{crit}<v<sub>m</v<sub>	
Height above Ground z _{crit} +h _s	SINGLE		SINGLE				*(V _{crit} -V _{touch})/(V _m -V _{touch}) if V _{cr}	rit>V _m
Table of Plume-averaged Vertical Velocities:								
Height (feet)	(meters)	Plume	Vert.					
above ground					Cinala Di	no Ean-		
Top of jet = 145.9 200.0	22.92 39.41	3.670 4.923	13.84 8.81	-	Single Plun) ² -(6.25D-z _v) ²]} ^{1/3} / a	
300.0	39.41 69.89	9.800			$v_{plume} = \{(va)_o \\ a = 0.16(z - 10) \}$		(0.200-2 ₁ /]} / d	
400.0	100.37	14.677	5.69				$_{xit}D^2/(4V_{plume}*a^2*\lambda^2)))$	
500.0	130.85	19.553						
600.0	161.33	24.430						
700.0	191.81	29.307	4.48					
800.0	222.29							
Begin Merging (touch) = 821.0	228.69	35.210	4.21		Interpolated			
900.0	252.77	#N/A	4.19		v:=V _{touch} +(V _m -V _{touch})*(z'-z _{touch})/(z _{full} -z _{touch})	
1000.0 1100.0	283.25 313.73		4.15 4.12					
1200.0	344.21	#N/A	4.12					
1300.0	374.69	#N/A	4.05					
1400.0	405.17	#N/A						
1500.0	435.65		3.99					
End Merging (full/mp) = 1543.0	448.76	83.744	3.97		Merged Plu			
1600.0	466.13				V={N(V³a) _f			
1700.0	496.61	91.399			a=a _m +0.16	(∠-Zfull)		
1800.0 1900.0	527.09 557.57	96.276 101.153			-			
2000.0	588.05				1			
2200.0	649.01	115.783						
2400.0	709.97	125.537	3.47					
2600.0	770.93							
2800.0	831.89							
3000.0	892.85		3.24					
3500.0	1045.25		3.08					
4000.0	1197.65	203.565						
	1350.05	227.949	2.85					
4500.0 5000.0	1502.45							



	"Aviation Sa	fety and Buo	yant Plumes	," Peter Be	st, et. al.			
	"The Evaluat	ion of Maxin	num Updraft	Speeds for	Calm Cond	ditions at V	arious Heights in the Plume	
			-	-			, Australia," Dr. K.T. Spillane	
Ambient Conditions:					-		eutral conditions (dθ/dz=0 or θ _a =	
Ambient Potential Temp θ _a	291.48	Kelvins	65.0				meters/feet	
Plume Exit Conditions:					Gravity g	9.81	m/s ²	
Stack Height h _s	21.549	meters	70.70	feet	λ	1.11		
Stack Diameter D	3,6698	meters	12.04	feet	λο	~1.0		
Stack Velocity V _{exit}	27.097			ft/sec	7.0			
Volumetric Flow		cu.m/sec	607,299		$\pi V_{exit} D^2/4$			Sect.2/¶1
					IIV exitD /4			3ect.2/1/1
Stack Potential Temp θ _s		Kelvins	839.1	T	N 5244	0.70.774	15	0 100
Initial Stack Buoyancy Flux F _o	533.45						ol.Flow(g/ π)(1- θ_a/θ_s)	Sect.2/¶1
Plume Buoyancy Flux F	N/A	m ⁴ /s ³			λ²gVa²(1-θ	_a /θ _p) for a,V	',θ _p at plume height (see below)	
Conditions at End (Top) of Jet Phase:								
Height above Stack z _{jet}		meters*	75.3		$z_{jet} = 6.25E$), meters*=	meters above stack top	Sect.3/¶1
Height above Ground z _{jet} +h _s		meters	145.9					
Vertical Velocity V _{jet}	13.549	m/s	44.45	ft/sec	V _{jet} = 0.5V	exit = V _{exit} /2		
Plume Top-Hat Diameter 2a _{jet}	7.340	meters	24.1	feet	2a _{jet} = 2D		Conservation of momentum	
pillane Methodology - Analytical Solutions	for Calm Con	ditions for Pl	ume Heights	s above Jet	Phase			
Single Plume-averaged Vertical Velocity	V given by Ar	nalytical Sol	ution in Pap	er where P	roduct Va	given by e	quations below:	
Plume Top-Hat Radius a	S	olutions in T	able Below		0.16(z-z _v),	or linear inc	crease with height	Sect.2/Eq.6
Virtual Source Height z _v	8.358	meters*	27.4	feet*	6.25D[1-(θ ₆	$_{\rm e}/\theta_{\rm s})^{1/2}], \ {\rm met}$	ers*=meters above stack top	Sect.2/Eq.6
Height above Ground z _v +h _s	29.907	meters	98.1	feet			where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2} =$	0.6356
Vertical Velocity V		olutions in T			${(Va)_o}^3 + 0$.12F _o [(z-z	_v) ² - (6.25D-z _v) ²]} ^(1/3) / a	Sect.2.1(6
Product (Va) _o	31.601				V _{exit} D/2(θ _e /			,,
	2201					-,		
Solve for plume-averaged vertical velo	city at height	1,000.0	feet	304 8	meters abo	we around ('z'+h_)	
Gives the following Height above Stack z'	283.251		929.3		meters abo	we ground (Z '11s)	
					0 1 000 10			0 10/5 (
Plume Top-Hat Diameter 2a'		meters	288.6		2a'=2*0.16	,		Sect.2/Eq.6
Vertical Velocity V	3.850	m/s	12.63	ft/sec	V={(Va) ₀ 3+	0.12F _o [(z-z	v) ² -(6.25D-z _v) ²]} ^(1/3) /(2a'/2)	Sect.2/Eq.6
Solve for Height of CASC critical vertical	velocity V _{crit}	5.30	m/s plume-a	everaged v		-		
Find Height above Stack z _{crit}	115.880	meters	380.2	feet	Solve for x	=(z-z _v) simi	ultaneously in both eqs. (i.e., Va	a and a)
Height above Ground z _{crit} +h _s	137.429	meters	450.9	F4				
			450.5	reet	tor V=4.3 n	n/s using th	ne cubic equation ax3+bx2+cx+d	I=0, where
based on Brig	g's equations		450.5	reet	tor V=4.3 n		· · · · · · · · · · · · · · · · · · ·	l=0, where -104.97
			226.8			a=1, c=	0, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)=	-104.97
Find Height above Stack z _{crit}	69.143	meters	226.8	feet		a=1, c=	=0, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= $_{0}(6.25D-z_{v})^{2}$ -(Va) _o ³]/(4.3 ³ 0.16 ³)=	-104.97 -294
	69.143			feet		a=1, c= d d=[0.12F _c	=0, and b=- $(0.12F_o)/(4.3^30.16^3)$ = $(6.25D-z_v)^2-(Va)_o^3]/(4.3^30.16^3)$ = http://www.1728.	-104.97 -294 org/cubic.h
Find Height above Stack z _{crit}	69.143	meters	226.8	feet		a=1, c= d d=[0.12F _c	0, and b=- $(0.12F_0)/(4.3^30.16^3)$ = $(6.25D-z_v)^2-(Va)_o^3/(4.3^30.16^3)$ = http://www.1728.	-104.97 -294 org/cubic.ht
Find Height above Stack z_{crit} Height above Ground z_{crit} + h_s	69.143 90.692	meters meters	226.8 297.5	feet feet	and	a=1, c= d d=[0.12F _c	=0, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= $_{2}$ (6.25D-z _v) ² -(Va) ₀ ³)/(4.3 ³ 0.16 ³)=	-104.97 -294 org/cubic.ht 107.52 115.8
Find Height above Stack z_{cnt} Height above Ground z_{cnt} + h_s Fable of Plume Top-Hat Diameters (2a) and F	69.143 90.692 Plume-averag	meters meters	226.8 297.5 Velocities sta	feet feet arting at en	and	a=1, c= d d=[0.12F _c g	e0, and b= $(0.12F_o)/(4.3^30.16^3)$ = $(6.25D-z_v)^2-(Va)_o^3]/(4.3^30.16^3)$ = http://www.1728. ives the real solution x = z-zv = or z(m) = z(ft) =	-104.97 -294 org/cubic.ht 107.52 115.8
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet)	69.143 90.692 Plume-averag (meters)	meters meters ed Vertical V	226.8 297.5 Velocities sta Vert.	feet feet arting at en	and	a=1, c= d d=[0.12F _c g ase: Brigg's	20, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= (6.25D-z _v) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728. ives the real solution x z-zv = or z(m) = z(t) = V _{Briggls} = (2/3) x 1.6 ⁽²⁰⁾ x F ^(1/2) x u ^(1/2) ,	-104.97 -294 org/cubic.ht 107.52 115.8
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground	69.143 90.692 Plume-averag (meters) above stack	meters meters ed Vertical \ Plume Radius(m)	226.8 297.5 /elocities state Vert. Vel(m/s)	feet feet arting at en	and	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR	e0, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= (6.25D-z _V) ² -(Va) _o ³)/(4.3 ³ 0.16 ³)= http://www.1728. iives the real solution x = z-zv = or z(m) = z(ft) = Va _{Biggla} = (2/3) x 1.6 ⁽³²⁾ x f ⁽¹²⁾ x u ⁽¹²⁾ ,	-104.97 -294 org/cubic.ht 107.52 115.8
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground <i>Top of jet</i> = 145.9	69.143 90.692 Plume-averag (meters) above stack 22.92	meters meters ed Vertical V Plume Radius(m) 3.670	226.8 297.5 Velocities stat Vert. Vel(m/s) 13.55	feet feet arting at en Plume Temp(K)	and	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21	20, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= (6.25D-z _V) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728. ives the real solution x = z-zv = or z(m) = z(ft) = V _{Briggla} = (2/3) x 1.6 ^(2/2) x f ^(1/2) x u ^{1/2)} , 0.50 m/s windspeed Spillane Equations:	-104.97 -294 org/cubic.h 107.52 115.8 380 x z ^(-1/2)
Find Height above Stack z_{cnt} Height above Ground z_{cnt} + h_s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41	meters meters ed Vertical V Plume Radius(m) 3.670 4.968	226.8 297.5 Velocities state Vert. Vel(m/s) 13.55 8.66	feet feet arting at en Plume Temp(K)	and	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21 7.02	e0, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= (6.25D-z _v) ² -(Va) _o ³)/(4.3 ³ 0.16 ³)= http://www.1728. ives the real solution x = z-zv = or z(m) = z(ft) = V _{Brags} = (2/3) x 1.6 ⁽³²⁾ x F ⁽¹²⁾ x U ⁽¹²⁾ , 0.50 m/s windspeed Spillane Equations: V _{plum} =-((Va) _o ³ -0.12F _o (z-z _v) ² -(6.25D	-104.97 -294 org/cubic.h 107.52 115.8 380 x z ^(-1/2)
Find Height above Stack z_{cnt} Height above Ground z_{cnt} + h_s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89	meters meters ed Vertical V Plume Radius(m) 3.670 4.968 9.845	226.8 297.5 Velocities state Vert. Vel(m/s) 13.55 8.66 6.49	feet feet rrting at en Plume Temp(K) 351.65 311.94	and	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21 7.02 5.27	$\begin{array}{l} \text{E0, and b=-}(0.12F_{\text{o}})(4.3^{3}0.16^{3}) = \\ \text{(6.25D-z.)^{2}-(Va)_{\text{o}}^{3})(4.3^{3}0.16^{3}) = \\ & \text{http://www.1728.} \\ \text{lives the real solution x = z-v.} = \\ & \text{or } z(m) = \\ & \text{or } z(m) = \\ & \text{Of, b} = \\ \text{V}_{\text{Briggs}} = (2/3) \times 1.6^{(3/2)} \times F^{1/2} \times V^{1/2/2}, \\ & \text{0.50 m/s windspeed} \\ \text{Spillane Equations:} \\ & \text{V}_{\text{plum}} = \{V(a)_{\text{o}}^{3} \cdot 40.12F_{\text{o}}((z-z_{\text{o}})^{2} \cdot (6.25D_{\text{o}})) = 0.16(2-z_{\text{o}})^{2} \cdot (6.25D_{\text{o}}) = 0.16(2-z_{\text{o}})^{2} \cdot (6.25D_{\text{o}}) \end{array}$	-104.97 -294 org/cubic.hi 107.52 115.8 380 x z ^(-1/2)
Find Height above Stack $z_{\rm crit}$ Height above Ground $z_{\rm crit}$ +h $_{\rm s}$ Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41	meters meters ed Vertical V Plume Radius(m) 3.670 4.968	226.8 297.5 Velocities state Vert. Vel(m/s) 13.55 8.66	feet feet rrting at en Plume Temp(K) 351.65 311.94	and	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21 7.02 5.27	e0, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= (6.25D-z _v) ² -(Va) _o ³)/(4.3 ³ 0.16 ³)= http://www.1728. ives the real solution x = z-zv = or z(m) = z(ft) = V _{Brags} = (2/3) x 1.6 ⁽³²⁾ x F ⁽¹²⁾ x U ⁽¹²⁾ , 0.50 m/s windspeed Spillane Equations: V _{plum} =-((Va) _o ³ -0.12F _o (z-z _v) ² -(6.25D	-104.97 -294 org/cubic.h 107.52 115.8 386 x z ^(-1/2) -z _{-v}) ²]) ^{1/3} / a
Find Height above Stack z_{cnt} Height above Ground z_{cnt} + h_s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89	meters meters ed Vertical V Plume Radius(m) 3.670 4.968 9.845	226.8 297.5 Velocities state Vert. Vel(m/s) 13.55 8.66 6.49	feet feet rrting at en Plume Temp(K) 351.65 311.94	and	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21 7.02 5.27	$\begin{array}{l} {\rm e0, and b = -(0.12F_o)/(4.3^30.16^3) = } \\ {\rm e(6.25D - z_v)^2 - (Va)_o}^3/(4.3^30.16^3) = } \\ {\rm http://www.1728.} \\ {\rm ives the real solution x z - zv = } \\ {\rm or z(m) = } \\ {\rm c(ft) = } \\ {\rm Va}_{\rm singly} = (2/3) x 1.6^{(3/2)} x F^{1/2} x v^{1/2/3}, \\ {\rm 0.50 m/s windspeed} \\ {\rm Spillane Equations:} \\ {\rm V}_{\rm pium} = {\rm I}(Va)_o^3 \cdot 40.12F_o[(z - z_v)^2 - (6.25D_o) = 0.16(z - z_v)] \\ {\rm e}_{\rm p} = {\rm e}_{\rm s}(1 + (1 - ({\rm e}_{\rm b}/{\rm e}_{\rm s}))^* (V_{\rm ext}D^2/(4V_{\rm ext}D^2/(4V_$	-104.97 -294 org/cubic.h 107.52 115.8 386 x z ^(-1/2) -z _{-v}) ²]) ^{1/3} / a
Find Height above Stack z_{crit} Height above Ground z_{crit} + h_s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of $jet = 145.9$ 200.0 300.0 400.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37	meters meters ed Vertical V Plume Radius(m) 3.670 4.968 9.845 14.722 19.599	226.8 297.5 Velocities state Vert. Vel(m/s) 13.55 8.66 6.49 5.60	feet feet Plume Temp(K) 351.65 311.94 302.08	and	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21 7.02 5.27 4.40	$\begin{aligned} & \cdot 0, \text{ and } b - (0.12F_o)/(4.3^30.16^3) = \\ & \cdot (6.25D - z_v)^2 - (Va)_o^3)/(4.3^30.16^3) = \\ & \cdot \text{http://www.} 1728. \end{aligned}$ ives the real solution $x = z - v = \\ & \text{or } z(m) = $	-104.97 -294 org/cubic.h 107.52 115.8 386 x z ^(-1/2) -z _{-v}) ²]) ^{1/3} / a
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85	meters meters ed Vertical V Plume Radius(m) 3.670 4.968 9.845 14.722 19.599	226.8 297.5 /elocities stat	feet feet Plume Temp(K) 351.65 311.94 302.08 298.09	and	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21 7.02 5.27 4.40 3.85	$\begin{array}{l} {\rm e0, and b = -(0.12F_o)/(4.3^30.16^3) = } \\ {\rm e(6.25D - z_v)^2 - (Va)_o}^3/(4.3^30.16^3) = } \\ {\rm http://www. 1728.} \\ {\rm ives the real solution x = z - z v = } \\ {\rm or z(m) = } \\ {\rm cm/m} \\ {\rm vergs} = (2/3) \times 1.6^{(2/3)} \times F^{1/2} \times v^{1/2/3}, \\ {\rm unition} \\ {\rm vergs} = (2/3) \times 1.6^{(2/3)} \times F^{1/2/3} \times v^{1/2/3}, \\ {\rm unition} \\ {\rm vergs} = (2/3) \times 1.6^{(2/3)} \times F^{1/2/3} \times v^{1/2/3}, \\ {\rm unition} \\ $	-104.97 -294 org/cubic.h 107.52 115.8 386 x z ^(-1/2) -z _{-v}) ²]) ^{1/3} / a
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33	meters meters meters ed Vertical Plume Radius(m)	226.8 297.5 /elocities state	feet feet Plume Temp(K) 351.65 311.94 302.08 298.09 296.06	and	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21 7.022 5.27 4.40 3.85 3.47 3.18	$\begin{array}{l} {\rm e0, and b = -(0.12F_o)/(4.3^30.16^3) = } \\ {\rm e(6.25D - z_v)^2 - (Va)_o}^3]/{\rm e(4.3^30.16^3) = } \\ {\rm http://www.1728.} \\ {\rm inves the real solution x = z - zv = } \\ {\rm or z(m) = } \\ {\rm z(ft) = } \\ {\rm Va_{\rm leggls} = (2/3) x 1.6^{(32)} x f^{(1/2)} x f^{(1/2)}, } \\ {\rm 0.50 m/s windspeed} \\ {\rm Spillane Equations:} \\ {\rm V_{\rm plume} = f(Va)_o^3 \cdot 40.12F_o((z - z_v)^2 - (6.25D a = 0.16(z - z_v) } \\ {\rm \theta_p = \theta_s(1 + (1 - (\theta_0/\theta_s))^*(V_{\rm exil}D^2/(4V_{\rm plume})^2)} \\ {\rm volume} = {\rm volume} \left({\rm volume} \left({\rm volume} \right) \left({\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \right) \right) \\ {\rm volume} \left({\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \left({\rm volume} \right) \right) \\ {\rm volume} \left({\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \left({\rm volume} \right) \left({\rm volume} \right) \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volume} \right) \left({\rm volume} \right) \\ {\rm volume} \left({\rm volum$	-104.97 -294 org/cubic.h 107.52 115.8 386 x z ^(-1/2) -z _{-v}) ²]) ^{1/3} / a
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81	meters meters meters Plume Radius(m) 4.968 9.845 14.722 19.599 24.476 29.352 34.229	226.8 297.5 /elocities stat Vert. Vel(m/s) 13.55 8.66 6.49 5.60 5.07 4.69 4.41	feet feet Plume Temp(K) 351.65 311.94 302.08 298.09 296.06 294.86	and	a=1, c= d d=[0.12F _c] g ase: Brigg's: Grad'PR 9.21 7.02 5.27 4.40 3.85 3.47 3.18	$\begin{array}{l} \text{20, and b=-}(0.12F_{\text{o}})(4.3^30.16^3) = \\ (6.25D\text{-z}_{\text{v}})^2\text{-}(Va)_{\text{o}}^3)/(4.3^30.16^3) = \\ & \text{http://www.1728.} \\ \text{lives the real solution x = z-zv =} \\ & \text{or z(m)} = \\ & \text{z(ft)} = \\ & \text{V}_{\text{Brggs}} = (2/3) \times 1.6^{327} \text{x f}^{1/2}, \text{x f}^{1/2}, \\ & \text{0.50 m/s windspeed} \\ \text{Spillane Equations:} \\ & \text{V}_{\text{plum}} = \{(Va)_{\text{o}}^3 + 0.12F_{\text{o}}[(z-z_{\text{o}})^2 + (6.25D_{\text{o}} + 2)^2 $	-104.97 -294 org/cubic.h 107.52 115.8 386 x z ^(-1/2) -z _{-v}) ²]) ^{1/3} / a
Find Height above Stack z_{crit} Height above Ground z_{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 820.1	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29	meters meters ed Vertical \(\text{Plume} \) Radius(m) 3.670 4.9868 9.845 14.722 19.599 24.476 29.352 34.229 35.209	226.8 297.5 /elocities station Vert. Vel(m/s) 13.55 8.666 6.49 5.60 5.07 4.69 4.41 4.19	feet feet Feet Feet Feet Feet Feet Feet	and d of jet pha	a=1, c= d d=[0.12F _c] g ase: Brigg's Grad'PR 9.21 7.02 5.27 4.40 3.85 3.47 3.18 2.96	Eq. and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= $(6.25D-z_v)^2$ -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728. ives the real solution $x=z-v=$ or $z(m)=$ z(m)= V _{Brighs} = (2/3) x 1.6 ^(3/2) x F ^(1/2) x V ^(1/2) , 0.50 m/s windspeed Spillane Equations: V _{plum} =1(Va) _o ³ +0.12F _o [(z-z _v) ² -(6.25D a = 0.16(z-z _v) θ_p = θ_o (1+(1-(θ_0/θ_o))*(V _{ext} D ² /(4V	-104.97 -294 org/cubic.h 107.52 115.8 386 x z ^(-1/2) -z _{-v}) ²]) ^{1/3} / a
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 Begin Merging (touch) = 820.1	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42	meters meters meters Plume Radius(m) 3.670 4.968 14.722 19.599 24.476 29.352 34.229 35.209 39.106	226.8 297.5 Velocities state Vert. Vel(m/s) 13.55 6.64 49 5.60 5.07 4.69 4.41 4.11 4.11 4.11 4.15	feet feet feet Feet Feet Feet Feet Feet	and d of jet pha	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21 7.02 5.27 4.40 3.85 3.47 3.18 2.996 2.92	$\begin{aligned} & \{0, \text{ and b} = \{0, 12F_o\}/(4.3^30.16^3) = \\ & \{(6.25D-z_v)^2 - (Va)_o\}^3\}/(4.3^30.16^3) = \\ & \frac{\text{http://www.1728.}}{\text{http://www.1728.}} \end{aligned}$ ives the real solution $x = z - v = \\ & \text{or } z(m) = \\ & \text{or } z(m) = \\ & \text{Otherwise} = (2/3) \times 1.6^{32/3} \times F^{1/2} \times u^{1/2}, \\ & \text{0.50 m/s windspeed} \end{aligned}$ Spillane Equations: $& \text{Spillane Equations:} \\ & \text{a} = 0.16(z - z_v) \\ & \theta_p = \theta_s (1 + (1 - (\theta_e/\theta_s))^*(V_{exit}D^2/(4V_{exit})^2 + (4 - (4 - (4 - (4 - (4 - (4 - (4 - (4$	-104.97 -294 orq/cubic.h 107.52 115.8 38i x z ^(-1/2)
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 Begin Merging (touch) = 820.1 900.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25	meters meters meters Plume Radius(m) 3.670 4.968 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983	226.8 297.5 /elocities state	feet feet Feet Feet Feet Feet Feet Feet	and d of jet pha	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21 7.02 5.277 4.40 3.85 3.47 3.18 2.96 2.99 2.277 2.62	10 , and b=-(0.12F _o)/(4.3 3 0.16 3)= (6.25D-z _v) ² -(Va) _o ³)/(4.3 3 0.16 3)= http://www.1728. iives the real solution x = z-zv = or z(m) = 10 (fig. 2) 10 (10 0.50 m/s windspeed Spillane Equations: 10 10.50 m/s windspeed Spillane Equations: 10 20.50 m/s windspeed a = 0.16(z-z _v) 10 6.25D a = 0.16(z-z _v)	-104.97 -294 orq/cubic.h 107.52 115.8 38i x z ^(-1/2)
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 820.1 900.0 1000.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25	meters meters meters Plume Radius(m) 3.670 4.968 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983 48.860	226.8 297.5 /elocities state	feet feet Feet Feet Feet Feet Feet Feet	and d of jet pha	a=1, c= d d=[0.12F _c] 9 ase: Brigg's Grad'PR 9.21 7.02 5.27 4.40 3.85 3.47 3.18 2.96 2.97 2.77 2.62	c_0 , and b=-(0.12F _o)/(4.3 3 0.16 3)= (6.25D-z _V) ² -(Va) _o ³)/(4.3 3 0.16 3)= http://www.1728. vives the real solution x = z-zv = or z(m) = z(ft) = V _{Brags} = (2/3) x 1.6 ^(2/3) x F ^{1/2} x u ^{1/2/3} ; 0.50 m/s windspeed Spillane Equations: V _{plume} ={((Va) _o ³ -30.12F _o ([z-z _v) ² -(6.25D a = 0.16(z-z _v)) + (-6.9/6 _o))*(V _{ext} D ² /(4V	-104.97 -294 orq/cubic.h 107.52 115.8 38i x z ^(-1/2)
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 820.1 900.0 1100.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 263.25 313.73	meters meters meters Plume Radius(m) 4.968 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983 48.860 53.736	226.8 297.5 /elocities state	feet feet Feet Feet Feet Feet Feet Feet	and d of jet pha	a=1, c= d d=[0.12F _c] g ase: Brigg's Grad'PR 9.21 7.02 5.27 4.40 3.85 3.47 3.18 2.96 2.92 2.49 2.38	Eq. and b=-(0.12F _o)/(4.3³0.16³)= (6.25D-z _V)²-(Va) _o ³]/(4.3³0.16³)= http://www.1728. ives the real solution $x = z-zv = or z(m) = z(f) = (2/3) x 1.6°2° x f1/2; x^{1/2}; x^{1/2}$	-104.97 -294 orq/cubic.h 107.52 115.8 38i x z ^(-1/2)
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Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 820.1 900.0 1100.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 263.25 313.73	meters meters meters Plume Radius(m) 4.968 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983 48.860 53.736	226.8 297.5 /elocities state	feet feet feet feet feet feet feet feet	d of jet ph:	a=1, c= d d=[0.12F _c] g ase: Brigg's Grad'PR 9.21 7.02 5.27 4.40 3.85 3.47 3.18 2.96 2.92 2.49 2.38	Eq. and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= (6.25D-z.) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728. ives the real solution $x = z - v = c$ or $z(m) = c$ $v = $	-104.9i -294 org/cubic.h 107.52 115.8 38 x z ^(-1/2)
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 820.1 900.0 1100.0 1200.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25 313.73 344.21	meters meters meters Plume Radius(m) 3.670 4.968 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983 48.800 53.736 58.613 63.490	226.8 297.5 /elocities state Vert. Vel(m/s) 13.55 8.666 6.49 5.60 5.07 4.69 4.41 4.19 4.15 4.01 3.85 3.727 3.60 3.500	feet feet feet feet feet feet feet feet	d of jet ph:	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21 7.020 5.27 4.40 3.85 3.47 3.18 2.96 2.92 2.77 2.62 2.49 2.48	$ \begin{aligned} & \{0, \text{and b} = \{0, 12F_o\}/(4.3^30.16^3) = \\ & \{(6.25D-z_v)^2 - \{Va)_o\}^3\}/(4.3^30.16^3) = \\ & \frac{\text{http:}//www.1728.}{\text{http:}//www.1728.} \end{aligned} $ ives the real solution $x = z - v = \\ & \text{or } z(m) = \\ & \text{or } z(m) = \\ & \text{or } z(m) = \\ & \text{otherwise} = \{2/3) \times 1.6^{302} \times F^{1/2} \times v^{1/2}, \\ & \text{0.50 m/s windspeed} \end{aligned} $ Spillane Equations: $ V_{\text{pluma}} = \{(Va)_o^3 \cdot 4.12F_o[(z-z_v)^2 - (6.25D_o^2) + (6.25D_o^2)^2 - (6.25D_o^2) + (1.4(-6_o/\theta_o))^2 + (6.25D_o^2)^2 - (6.25D_o^2)^2 - (6.25D_o^2) + (1.4(-6_o/\theta_o))^2 + (6.25D_o^2)^2 - $	-104.9i -294 org/cubic.h 107.52 115.8 38 x z ^(-1/2)
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 800.0 Begin Merging (touch) = 820.1 900.0 1000.0 1100.0 1200.0 1300.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25 313.73 344.21 374.69 405.17	meters meters meters Plume Radius(m) 3.670 4.968 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983 48.800 53.736 58.613 63.490	226.8 297.5 Velcities state Vert. Vel(m/s) 13.55 6.04 5.60 5.07 4.69 4.41 4.19 4.15 4.01 3.85 3.72 3.60 3.50 3.40	feet feet feet feet feet feet feet feet	d of jet ph:	a=1, c= d d=[0.12F _c g g ase: Brigg's Grad'PR 9.21 7.022 5.27 4.40 3.85 3.47 3.18 2.966 2.92 2.77 2.62 2.49 2.38 2.288 2.288	20, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= (6.25D-z _v) ² -(Va) _o ³)/(4.3 ³ 0.16 ³)= http://www.1728. ives the real solution x = z-zv = or z(m) = cft) = V _{Briggs} = (2/3) x 1.6 ^(3/2) x F ^(1/2) x u ^(1/2) , 0.50 m/s windspeed Spillane Equations: a = 0.16(z-z _v) θ _p =θ _s (1+(1-(θ _e /θ _s))*(V _{exil} D ² /(4V	-104.97 -294 orq/cubic.h 107.52 115.8 38i x z ^(-1/2)
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 820.1 900.0 1100.0 1200.0 1300.0 1400.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25 313.73 344.21 374.69 405.17	meters meters meters Plume Radius(m) 3.670 4.988 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983 48.860 53.736 58.613 63.4990 68.367 70.420	226.8 297.5 /elocities stat Vert. Vel(m/s) 13.55 8.66 6.449 5.60 5.07 4.69 4.41 4.19 4.15 4.01 3.85 3.72 3.60 3.505 3.40 3.32	feet feet feet feet feet feet feet feet	d of jet ph:	a=1, c= d d=[0.12F _c g gase: Brigg's Grad'PR 9.21 7.02 5.277 4.40 3.85 3.47 3.18 2.96 2.92 2.77 2.62 2.49 2.28 2.28 2.28 2.21 2.21	10 , and b=-(0.12F _o)/(4.3 3 0.16 3)= (6.25D-z _v) ² -(Va) _o ³)/(4.3 3 0.16 3)= http://www.1728. iives the real solution x = z-zv = or z(m) = z(ft) = Vargas = (2/3) x 1.6 $^{(2/3)}$ x F ^{1/2} x U ^{1/2} ; 0.50 m/s windspeed Spillane Equations: V_{plume} =((Va) _o ³ +0.12F _o (z-z _v) ² -(6.25D a = 0.16(z-z _v) θ_{p} = θ_{s} (1+(1-(θ_{e} / θ_{e}))*(VexilD ² /(4V	-104.97 -294 orq/cubic.h 107.52 115.8 38i x z ^(-1/2)
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Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 800.0 Begin Merging (touch) = 820.1 900.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1542.1 1600.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 263.25 313.73 344.21 374.69 405.17 435.65 448.48 466.13	meters meters meters Plume Radius(m) 3.670 4.9868 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983 48.860 53.796 68.367 70.420 73.244 78.120	226.8 297.5 /elocities state Vert. Vel(m/s) 13.55 8.666 6.49 5.60 5.07 4.69 4.41 4.19 4.15 4.01 3.85 3.727 3.60 3.30 3.40 3.32 3.22 3.25 3.325 3.318	feet feet feet feet feet feet feet feet	d of jet ph:	a=1, c= d d=[0.12F _c g ase: Brigg's Grad'PR 9.21 7.020 5.27 4.40 3.85 3.47 2.96 2.92 2.77 2.62 2.49 2.28 2.19 2.11 2.08 2.04	$\epsilon 0$, and b=-(0.12F _o)/(4.3 3 0.16 3)= (6.25D-z.) ² -(Va) _o ³]/(4.3 3 0.163)= http://www.1728.ives the real solution x z-z-v or z(m) = z(ft) = V _{Bragh} = (2/3) x 1.6 ^(3/2) x F ^(1/2) x V ^(1/2) , 0.50 m/s windspeed Spillane Equations: V _{plum} ={(Va) _o ³ -0.12F _o [(z-z.) ² -(6.25D a = 0.16(z-z.))} θ _p =θ _o (1+(1-(θ _o /θ _o))*(V _{extl} D ² /(4V	-104.97 -294 orq/cubic.h 107.52 115.8 38i x z ^(-1/2)
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 800.0 Begin Merging (touch) = 820.1 900.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1542.1 1600.0 1700.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.48 466.13	meters meters meters Plume Radius(m) 3.670 4.9668 9.845 14.722 19.599 24.476 29.352 34.229 39.106 43.983 48.860 53.736 58.613 63.490 68.367 70.420 73.2444 78.120 82.997	226.8 297.5 Velcities state Vert. Vel(m/s) 13.55 6.649 5.60 6.49 4.41 4.19 4.15 4.01 3.85 3.72 3.606 3.50 3.40 3.32 3.22 3.22 3.25 3.18	feet feet feet feet feet feet feet feet	d of jet pha	a=1, c= d d=[0.12F _c g g ase: Brigg's Grad'PR 9.21 7.022 5.27 4.40 3.85 3.47 3.18 2.966 2.92 2.77 2.62 2.49 2.38 2.28 2.19 2.11 2.08 2.04 1.98	$\epsilon 0$, and b=-(0.12F _o)/(4.3 3 0.16 3)= (6.25D-z _v) ² -(Va) _o ³)/(4.3 3 0.16 3)= http://www.1728. ives the real solution x z-zv = or z(m) = z(t)	-104.97 -294 org/cubic.h 107.52 115.8 386 x z ^(-1/2)
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 600.0 700.0 800.0 Begin Merging (touch) = 820.1 900.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1542.1 1600.0 1700.0 1700.0 1700.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.48 466.13 496.61 527.09	meters meters meters Plume Radius(m) 3.670 4.968 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983 48.800 63.490 68.367 70.420 73.244 78.120 82.997 87.874	226.8 297.5 /elocities stat Vert. Vel(m/s) 13.55 8.66 6.494 5.60 5.07 4.69 4.41 4.19 4.15 4.01 3.88 3.72 3.80 3.30 3.30 3.32 3.29 3.25 3.18 3.11	feet feet feet feet feet feet feet feet	d of jet pha	a=1, c= d d=[0.12F _c g	E0, and b=-(0.12F _o)/(4.3³0.16³)= (6.25D-z _v)²-(Va) _o ³]/(4.3³0.16³)= http://www.1728. ives the real solution x = z-zv = or z(m) = c(tt) = V _{Briggs} = (2/3) x 1.6° ²² x F ^{1/2} x u ^{1/2}), 0.50 m/s windspeed Spillane Equations: V _{plums} =(V(Va) _o ³-0.12F _o [(z-z _v)²-(6.25D a = 0.16(z-z _v)) θ _p =θ _s (1+(1-(θ _e /θ _s))*(V _{exit} D²/(4V	-104.97 -294 orq/cubic.h 107.52 115.8 38i x z ^(-1/2)
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 800.0 800.0 800.0 1000.0 1100.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1542.1 1600.0 1700.0 1800.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.48 466.13 496.61 527.09 557.57	meters meters meters Plume Radius(m) 3.670 4.968 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983 48.860 53.736 58.613 63.490 68.367 70.420 73.244 78.120 82.997 87.874	226.8 297.5 /elocities state Vert. Vel(m/s) 13.55 8.66 6.494 5.60 5.07 4.69 4.41 4.19 4.15 4.01 3.85 3.77 3.60 3.40 3.32 3.29 3.25 3.18 3.11 3.05	feet feet feet feet feet feet feet feet	d of jet pha	a=1, c= d d=[0.12F _c g] ase: Brigg's Grad'PR 9.21 7.02 5.277 4.40 3.85 3.47 3.18 2.96 2.92 2.77 2.62 2.49 2.38 2.19 2.11 2.08 2.04 1.98 1.92 1.87	20, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= (6.25D-z _v) ² -(Va) _o ³)/(4.3 ³ 0.16 ³)= http://www.1728. ives the real solution x = z-zv = or z(m) = constant y = y = y = y = y = y = y = y = y = y	-104.97 -294 orq/cubic.h 107.52 115.8 38i x z ^(-1/2)
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and Fable of Plume Top-Hat Diameters (2a) and Fabre Ground Fable of Plume Top-Hat Diameters (2a) and Fabre Ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 820.1 900.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1542.1 1600.0 1700.0 1800.0 1900.0 1900.0 2000.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.48 466.13 496.61 527.09 557.57 588.05	meters meters meters Plume Radius(m) 3.670 4.988 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983 48.860 53.736 58.613 63.490 68.367 70.420 73.244 78.120 82.997 87.874 92.751 102.504	226.8 297.5 /elocities stat	feet feet feet feet feet feet feet feet	d of jet pha	a=1, c= d d=[0.12F _c g] ase: Brigg's Grad'PR 9.21 7.02 5.27 4.40 3.85 3.47 3.18 2.96 2.99 2.77 2.62 2.49 2.38 2.28 2.28 2.19 2.11 2.08 2.04 1.98 1.873	$\epsilon 0$, and b=-(0.12F _o)/(4.3 3 0.16 3)= (6.25D-z _v) ² -(Va) _o ³)/(4.3 3 0.16 3)= http://www.1728. iives the real solution x = z-zv = or z(m) = z(ft) = Vargas = (2/3) x 1.6 $^{(2/3)}$ x F ^(1/2) x U ^{1/2)} , 0.50 m/s windspeed Spillane Equations: V _{pluma} ={(Va) _o ² -0.12F _o (z-z _v) ² -(6.25D a = 0.16(z-z _v) θ _p = θ _o (1+(1-(θ _o / θ _o))*(V _{exil} D ² /(4V	-104.9i -294 org/cubic.h 107.52 115.8 38 x z ^(-1/2)
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Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 600.0 700.0 800.0 800.0 8egin Merging (touch) = 820.1 900.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1542.1 1600.0 1700.0 1800.0 1900.0 2000.0 2200.0 2200.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.48 466.13 496.61 527.09 557.57 588.05 649.01	meters meters meters Plume Radius(m) 3.670 4.968 9.845 14.722 19.599 24.476 29.352 34.229 35.209 39.106 43.983 48.860 63.367 70.420 73.244 78.120 82.997 87.874 92.751 102.504 112.258	226.8 297.5 /elocities state Vert. Vel(m/s) 13.55 8.666 6.49 5.60 5.07 4.69 4.41 4.19 4.15 4.01 3.85 3.72 3.60 3.50 3.40 3.32 3.22 3.25 3.18 3.11 3.05 3.00 2.90 2.81	feet feet feet feet feet feet feet feet	d of jet pha	a=1, c= d d=[0.12F _c	E0, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= (6.25D-z _v) ² -(Va) _o ³)/(4.3 ³ 0.16 ³)= http://www.1728. ives the real solution x z-zv = or z(m) = v _{angs} = (2/3) x 1.6 ^(3/2) x F ^(1/2) x v ^(1/2) , 0.50 m/s windspeed Spillane Equations: V _{plum} ={(Va) _o ³ -0.12F _o (z-z _v) ² -(6.25D a = 0.16(z-z _v) θ _p =θ _o (1+(1-(θ _e /θ _o))*(V _{ext} D ² /(4V	-104.97 -294 orq/cubic.h 107.52 115.8 38i x z ^(-1/2)
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Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and Fable of Plume Top-Hat Diameters (2a) and Fable of Plume Top-Hat Diameters (2a) and Fable of Jets 145.9 Region Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 800.0 800.0 800.0 800.0 800.0 1000.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1542.1 1600.0 1700.0 1800.0 1900.0 2000.0 2000.0 2400.0 2600.0 2600.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 169.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.48 466.13 496.61 527.09 557.57 588.05 649.01 709.97 770.93	meters meters meters Plume Radius(m) 3.670 4.968 9.845 14.722 19.599 24.476 29.352 35.209 39.106 43.983 48.860 53.736 58.6131 63.490 68.367 70.420 73.244 78.120 82.997 87.874 92.751 102.504 112.258 122.012 131.765 141.519	226.8 297.5 /elocities state Vert. Vel(m/s) 13.55 8.66 8.49 5.60 5.07 4.69 4.41 4.19 4.15 4.01 3.85 3.72 3.29 3.25 3.18 3.11 3.05 3.00 2.90 2.81 2.74	feet feet feet feet feet feet feet feet	d of jet pha	a=1, c= d d=[0.12F _c g	E0, and b=-(0.12F _o)/(4.3³0.16³)= (6.25D-z _v)²-(Va) _o ³)/(4.3³0.16³)= http://www.1728. ives the real solution x = z-zv = or z(m) = cm. (ft) = V _{Briggs} = (2/3) x 1.6° ²² x F ^{1/2} x u ^{1/2}), 0.50 m/s windspeed Spillane Equations: a = 0.16(z-z _v) θ _p =θ _s (1+(1-(θ _e /θ _s))*(V _{exil} D²²/(4V))	-104.97 -294 org/cubic.h 107.52 115.8 386 x z ^(-1/2)
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and Fable of Plume Top-Hat Diameters (2a) and Fable of Plume Top-Hat Diameters (2a) and Fable of Jets 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 800.0 800.0 800.0 800.0 1000.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1542.1 1600.0 1700.0 1800.0 1800.0 1900.0 2200.0 2200.0 2400.0 2600.0 2800.0	69.143 90.692 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 228.42 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.48 466.13 496.61 527.09 557.57 588.05 649.01 709.97 7770.93 831.89	meters meters meters Plume Radius(m) 3.670 4.988 9.845 14.722 19.599 24.476 29.352 34.229 39.106 43.983 48.860 53.736 58.613 63.490 68.367 70.420 73.244 78.120 82.997 87.874 92.751 102.504 112.258 122.012 131.765 141.519 165.903	226.8 297.5 /elocities state Vert. Vel(m/s) 13.55 8.66 6.44 5.60 5.07 4.69 4.41 4.01 3.85 3.72 3.60 3.30 3.30 3.29 3.25 3.18 3.11 3.05 3.00 2.90 2.81 2.74 2.67	feet feet feet feet feet feet feet feet	d of jet ph:	a=1, c= d d=[0.12F _c d d=[0.12F _c] 9 ase: Brigg's Grad'PR 9.21 7.02 5.277 4.40 3.85 3.47 3.18 2.96 2.92 2.77 2.62 2.49 2.38 2.282 2.19 2.11 2.08 2.04 1.92 1.87 1.82 1.73 1.65 1.53 1.47	20, and b=-(0.12F _o)/(4.3 ³ 0.16 ³)= (6.25D-z _v) ² -(Va) _o ³)/(4.3 ³ 0.16 ³)= http://www.1728. ives the real solution x = z-zv =	-104.97 -294 org/cubic.h 107.52 115.8 386 x z ^(-1/2)
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MERGED Plume Average Vertical Velocities			uoyant Plumes				3 -999 5	
						litions at \	/arious Heights in the Merg	ed
	THE Evalua						ueensland, Australia," Dr. H	
Ambient Conditions:							eutral conditions (dθ/dz=0 or	
Ambient Potential Temp θ _a	291.48	Kelvins	65.0	°F		0.3048	meters/feet	
Plume Exit Conditions:					Gravity g	9.81	m/s ²	
Stack Height h _s	21.549	meters	70.7	feet	λ	1.11		
Stack Diameter D	3.6698	meters	12.0	feet	λο	~1.0		
Number of Stacks N	2						e plume treatment in Peter Be	
Average Adjacent Stack Separation d		meters	231.04	feet			ised by N ^{0.25} at the height whe	
Stack Velocity V _{exit}	27.097	m/s	88.9	ft/sec	fully merged	(interp. be	low ht, single merged stack a	bove ht)
Volumetric Flow	286.61	cu.m/sec	607,299	ACFM	πV _{exit} D ² /4			Sect.2/¶1
Stack Potential Temp θ _s		Kelvins	839	°F				
Initial Stack Buoyancy Flux F _o		m4/s3					ol.Flow(g/ π)(1- θ_a/θ_s)	Sect.2/¶1
Plume Buoyancy Flux F	N/A	m4/s3			$\lambda^2 g Va^2 (1-\theta_a)$	θ_p) for a,V	,θ _p at plume height (see belo	w)
Conditions at End (Top) of Jet Phase:								
Height above Stack z _{jet}		meters*		feet*	$z_{jet} = 6.25D$	meters*=	meters above stack top	Sect.3/¶1
Height above Ground z _{jet} +h _s		meters	145.9					
Vertical Velocity V _{jet}	13.549			ft/sec	$V_{jet} = 0.5V_{ex}$	$_{\text{cit}} = V_{\text{exit}}/2$		
Plume Top-Hat Diameter 2a _{jet}	7.340	meters	24.1	feet	2a _{jet} = 2D		Conservation of momentum	
Spillane Methodology - Analytical Solutions								
Single Plume-averaged Vertical Velocity		-				-		
Single Plume Values: Plume Top-Hat Radius a			e Merging On				r increase with height	Sect.2/Eq.
Virtual Source Height z _v		meters*	1	feet*	$z_v = 6.25D[$	$1-(\theta_e/\theta_s)^{1/2}$, meters*=meters above stack top	
Height above Ground z _v +h _s		meters	98.1				where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2} =$	
Single Plume Values: Vertical Velocity V			e Merging On	у			,) ² - (6.25D-z _v) ²]} ^(1/3) / a	Sect.2.1(6
Product (Va) _o	31.601	m²/s			$V_{exit}(D/2)(\theta_{e}$	/θ _s) ^{1/2}		
Plume Merging - Based on Single Plume Cal								Sect.3/¶3
Begin Merging Plume Top-Hat Diameter 2atouch		meters	231.0		2a _{touch} =d, (c			
Height above Stack z _{touch}		meters*	749.4		$z_{touch} = z_v + \epsilon$	d/(2*0.16),	meters*=meters above stack	top
Height above Ground z _{touch} +h _s	249.970	meters	820.1	feet				
Vertical Velocity V _{touch}	4.149			ft/sec			$F_0 [(z-z_v)^2 - (6.25D-z_v)^2]$	
Total Merging Plume Top-Hat Diameter 2a _{full}	140.840	meters	462.1	feet			all=d(N-1)/2) FOR 2 STACKS,	
Height above Stack z _{full}	448.483	meters*	1471.4	feet*	$z_{full} = z_v + 2c$	/(2*0.16), 1	meters*=meters above stack	top
Height above Ground z _{full} +h _s	470.032	meters	1542.1	feet				
Vertical Velocity V _{full}	3.288	m/s	10.8	ft/sec	$V_{full} = \{(Va)_c$	3 + 0.12F _o	$[(z_{full}-z_v)^2 - (6.25D-z_v)^2]$	/ a _{full}
Product (V ³ a) _{full}	2,504	m ⁴ /s ³						
Conditions at End (Top) of Merging Phase - D	efine new valu	ies for V _{full} a	and a _{full} in Merg	ed Plume	e calculations:			
Merged Plume Values: Plume Diameter 2a	S	olutions in	Table Below		2a = 2 x (a _m	+ 0.16(z-	z _{full})), or linear increase with	height
Revised Merged Plume Radius a _m	83.744	meters	274.8	feet	where a _m =	N ^{0.25} a _{full} w	here Total Merging Occurs	
Revised Merged Plume Velocity V _m	3.911	m/s	12.83	ft/sec	and V _m =	$N^{0.25}V_{full}$ w	where Total Merging Occurs	
Revised Virtual Source Height zfull	448.483	meters*	1471.4	feet*	Height above	stack wh	ere Total Merging Occurs (sh	nown above
Revised Vertical Velocity V	S	olutions in	Tables Below		V={N(V3a)ful	/a}1/3 for h	eights above total merging el	evation
					V=V _{touch} +(V	m-V _{touch})*(2	z-z _{touch})/(z _{full} -z _{touch})	
Multiple Plume Calculations							for heights below total mergi	ng elevation
Solve for plume-averaged vertical veloc	ity at height	1,000.0	feet	304	1.8 meters abov	e ground (z+h _s)	
Gives the following Height above Stack z	283.251	meters*	929.3	feet*	LESS THAN	TOP OF	MERGING PHASE-INTERPO	LATE
Plume Top-Hat Radius a	#N/A	meters	#N/A	feet	a=a _m +0.16(2	z-z _{full}) if z>	Z _{full}	
Vertical Velocity V	4.090	m/s	13.42	ft/sec	V={N(V3a)ful	/a} ^{1/3} if z>	Z _{full}	
					V'=V _{touch} +(V	'm-V _{touch})*(z'-z _{touch})/(z _{full} -z _{touch}) if z _{touch}	<z<z<sub>full</z<z<sub>
					V'=single plu			
Solve for Height of CASC critical vertical	velocity V _{crit}	5.30	m/s		BEFORE TO			
Find Height above Stack z _{crit}	SINGLE	meters	SINGLE	feet	Z _{crit} = Z _{full} +	{[N(V³a) _{ful}	/(V _{crit}) ³]-a _m }/0.16 if V _{crit} <v<sub>m</v<sub>	
Height above Ground z _{crit} +h _s	SINGLE	meters	SINGLE	feet			*(V _{crit} -V _{touch})/(V _m -V _{touch}) if V _c	.:->V
J. C.					CIR TOUCH	Tun touchy	Citi todany (in todany C	
Table of Plume-averaged Vertical Velocities:								
Height (feet)	(meters)	Plume	Vert.					
above ground								
Top of jet = 145.9	22.92				Single Plum	e Eans		
200.0	39.41	-) ² -(6.25D-z,) ²]} ^{1/3} / a	
300.0	69.89	-	+		a = 0.16(z-z)		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	
400.0	100.37						$_{xit}D^2/(4V_{plume}*a^2*\lambda^2)))$	
500.0	130.85		1		-h os/1./1./	-e-s// (*e		
600.0	161.33		-					
700.0	191.81				+ +			
800.0	222.29				+			
Begin Merging (touch) = 820.1	228.42				Interpolated	I aver Eco	•	-
900.0	252.77							
1000.0	283.25				v -v _{touch} +(V	m" v touch)"(z'-z _{touch})/(z _{full} -z _{touch})	
					-			
1100.0	313.73 344.21				-			
1200.0			-		+			
1300.0	374.69				-			
1400.0	405.17	-	+					
1500.0	435.65				14.m. 151	5		
End Merging (full/mp) = 1542.1	448.48		4		Merged Plur			
1600.0	466.13				V={N(V ³ a) _{ful}			
1700.0	496.61				a=a _m +0.16(2	z-z _{full})		
	527.09		-					
1800.0	557.57		-					
1800.0 1900.0		106.075						
1900.0 2000.0	588.05		3.51					
1900.0	588.05 649.01	115.828	0.01					
1900.0 2000.0								
1900.0 2000.0 2200.0	649.01	125.582	3.42					
1900.0 2000.0 2200.0 2400.0	649.01 709.97	125.582 135.336	3.42 3.33					
1900.0 2000.0 2200.0 2400.0 2600.0	649.01 709.97 770.93	125.582 135.336 145.089	3.42 3.33 3.26					
1900.0 2000.0 2200.0 2400.0 2600.0 2800.0	649.01 709.97 770.93 831.89	125.582 135.336 145.089 154.843	3.42 3.33 3.26 3.19					
1900.0 2000.0 2200.0 2400.0 2600.0 2800.0 3000.0	649.01 709.97 770.93 831.89 892.85	125.582 135.336 145.089 154.843 179.227	3.42 3.33 3.26 3.19 3.03					
1900.0 2000.0 2200.0 2400.0 2600.0 2800.0 3000.0 3500.0	649.01 709.97 770.93 831.89 892.85 1045.25	125.582 135.336 145.089 154.843 179.227 203.611	3.42 3.33 3.26 3.19 3.03 2.91					



	"Aviation Sa		-	." Peter Ro		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	ing-Fogging ON)	
		-	-			ditions at V	arious Heights in the Plume	
	THE Evaluat		-	-			, Australia," Dr. K.T. Spillane	
Ambient Conditions:		nom a oas	raibine row				eutral conditions (dθ/dz=0 or θ _a =	=A)
Ambient Potential Temp θ _a	312 //3	Kelvins	102.7		Constants.		meters/feet	o _e ,
Plume Exit Conditions:	312.43	IXCIVIIIS	102.7		Gravity g		m/s ²	
Stack Height h	21 540	meters	70.70	foot	διανίτη g	1.11	III/S	
Stack Diameter D		meters	12.04		λο	~1.0		
Stack Velocity V _{exit}	26.579			ft/sec	N 5214			0 100
Volumetric Flow		cu.m/sec	595,689		πV _{exit} D ² /4			Sect.2/¶1
Stack Potential Temp θ _s		Kelvins	847.7	°F				
Initial Stack Buoyancy Flux F _o	500.25					,		Sect.2/¶1
Plume Buoyancy Flux F	N/A	m ⁴ /s ³			$\lambda^2 g Va^2 (1-\theta_i)$	$_{a}/\theta_{p})$ for a,V	,θ _p at plume height (see below)	
Conditions at End (Top) of Jet Phase:								
Height above Stack z _{jet}	22.936	meters*	75.3	feet*	$z_{jet} = 6.25E$), meters*=	meters above stack top	Sect.3/¶1
Height above Ground z _{jet} +h _s	44.485	meters	145.9	feet				
Vertical Velocity V _{jet}	13.290	m/s	43.60	ft/sec	$V_{jet} = 0.5V_e$	exit = V _{exit} /2		
Plume Top-Hat Diameter 2a _{jet}	7.340	meters	24.1	feet	2a _{jet} = 2D		Conservation of momentum	
pillane Methodology - Analytical Solutions	for Calm Con	ditions for Pl	ume Heights	s above Je	t Phase			
Single Plume-averaged Vertical Velocity	V given by Ar	nalytical Sol	ution in Pap	er where P	roduct Va	given by e	quations below:	
Plume Top-Hat Radius a	S	olutions in T	able Below		0.16(z-z _v),	or linear inc	crease with height	Sect.2/Eq.6
Virtual Source Height z _v	7.893	meters*	25.9	feet*	6.25D[1-(θ _ε	₂ /θ _s) ^{1/2}], met		Sect.2/Eq.6
Height above Ground z _v +h _s		meters	96.6				where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2} =$	
Vertical Velocity V		olutions in T			{(Va) _c ³ + 0	12F ₀ [(7-7		Sect.2.1(6
Product (Va) _o	31.986		510₩		((va) ₀ + 0. V _{evit} D/2(θ _e /		,, (0.200 £V)]] / a	J 5501.2. 1(C
Floudti (Va) ₀	31.800	111 /5			▼ exitU/∠(Ue/	US)		
Solve for plume-averaged vertical velo	city of helate	1,000.0	foot	204.0	meters abo	un grace d'	-'+b \	
	-				meters abo	we ground (Z +11 _S)	
Gives the following Height above Stack z'	283.251		929.3					
Plume Top-Hat Diameter 2a'		meters	289.1		2a'=2*0.16(,		Sect.2/Eq.6
Vertical Velocity V	3.767	m/s	12.36	ft/sec	V={(Va) _o 3+	0.12F _o [(z-z	v) ² -(6.25D-z _v) ²]} ^(1/3) /(2a'/2)	Sect.2/Eq.6
Solve for Height of CASC critical vertical	velocity V _{crit}	5.30	m/s plume-a	averaged v	ertical velo	ocity		
Find Height above Stack z _{crit}	109.382	meters	358.9	feet	Solve for x=	=(z-z _v) simu	ultaneously in both eqs. (i.e., Va	and a)
Height above Ground z _{crit} +h _s	130.931	meters	429.6	feet	for V=4.3 n	n/s using th	e cubic equation ax3+bx2+cx+d	=0, where
based on Brig	g's equations					a=1, c=	$(0.12F_0)/(4.3^30.16^3)$	-98.44
Find Height above Stack z _{crit}	64.840	meters	212.7	feet	and	d d=[0.12F _o	(6.25D-z _v) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)=	-313
		meters meters	212.7 283.4		and	d d=[0.12F _o		
Find Height above Stack z _{crit} Height above Ground z _{crit} +h _s					and		(6.25D-z _v) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728.e	org/cubic.h
					and		$(6.25D-z_v)^2-(Va)_o^3]/(4.3^30.16^3)= \frac{\text{http://www.1728.}}{\text{ives the real solution x = z-zv =}}$	org/cubic.h
Height above Ground z _{crit} +h _s	86.389	meters	283.4	feet		g	$(6.25D-z_v)^2-(Va)_o^3]/(4.3^30.16^3) = \frac{http://www.1728.0}{http://www.1728.0}$ ives the real solution x = z-zv = or z(m) =	101.48 109.3
Height above Ground $z_{crit} + h_s$ Table of Plume Top-Hat Diameters (2a) and F	86.389	meters	283.4 Velocities sta	feet		g ase:	$(6.25D-z_v)^2-(Va)_o^3)/(4.3^30.16^3)= http://www.1728.uives the real solution x = z-zv = or z(m) = z(ft) = (ft) = (f$	101.48 109.3
Height above Ground z _{crit} +h _s able of Plume Top-Hat Diameters (2a) and F Height (feet)	86.389 Plume-averag (meters)	meters ed Vertical V	283.4 Velocities sta Vert.	feet arting at en		g ase: Brigg's	$(6.25D-z_v)^2-(Va)_0^3]/(4.3^30.16^3)= $$ http://www.1728.ives the real solution x=z-zv= $$ or z(m) = $$ z(ft) = $$ V_{Beggs} = (2/3) \times 1.6^{(3/2)} \times F^{(1/2)} \times U^{(1/2)} \times U^{(1/2)} = (2/3) \times 1.6^{(3/2)} \times F^{(1/2)} \times U^{(1/2)} \times U^{(1/2)} = (2/3) \times 1.6^{(3/2)} \times U^{(1/2)} \times U^{(1/2)} \times U^{(1/2)} = (2/3) \times 1.6^{(3/2)} \times U^{(1/2)} \times U^{$	101.48 109.3
Height above Ground z _{crit} +h _s able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground	86.389 Plume-averag (meters) above stack	meters ed Vertical \(\text{Plume} \) Radius(m)	283.4 /elocities sta Vert. Vel(m/s)	feet arting at en		g ase: Brigg's Grad'PR	(6.25D-z _V) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728.ives the real solution x = z-zv = or z(m) = z(ft) = Va _{figgls} = (2/3) x 1.6 ^{(3/2} x f ^(1/2) x u ^{1/2)} y 0.50 m/s windspeed	101.48 109.3
Height above Ground z _{crit} +h _s able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground <i>Top of jet</i> = 145.9	86.389 Plume-averag (meters) above stack 22.92	ed Vertical Vertical Radius(m)	Z83.4 Velocities state Vert. Vel(m/s) 13.29	arting at en Plume Temp(K)		g ase: Brigg's Grad'PR 8.91	$\begin{array}{ll} (6.25D\text{-}z_{v})^{2} - (Va)_{o}^{3}) (4.3^{3}0.16^{3}) \\ & \underline{\text{http://www.1728.}} \\ \text{ives the real solution x = z-zv =} \\ & \text{or z(m) =} \\ & z(\text{ft}) = \\ V_{\text{Briggs}} = (2/3) \times 1.6^{(3/2)} \times F^{(1/2)} \times u^{(1/2)}, \\ & 0.50 \text{ m/s windspeed} \\ \\ \text{Spillane Equations:} \end{array}$	101.48 109.3 358 2 z ^(-1/2)
Height above Ground $z_{crit} + h_s$ able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0	Plume-averag (meters) above stack 22.92	ed Vertical V Plume Radius(m) 3.670	283.4 /elocities sta	ring at en Plume Temp(K)		g ase: Brigg's Grad'PR 8.91 6.80	$\begin{array}{ll} (6.25D\text{-}z_{v})^{2} - (Va)_{o}^{3}) (4.3^{3}0.16^{3}) \\ & \underline{\text{http://www.1728.}} \\ \text{ives the real solution x = z-zv =} \\ & c z (m) \\ & z (ft) = \\ & Va_{tigys} = (2/3) \times 1.6^{(3/2)} \times f^{(1/2)} \times u^{(1/2)} \times \\ & 0.50 \text{ m/s windspeed} \\ \\ \textbf{Spillane Equations:} \\ V_{\text{plum}} = ((Va)_{o}^{3} - 0.12F_{o}[(z-z_{v})^{2} - (6.25D - 1)] \\ \end{array}$	101.48 109.3 358 2 z ^(-1/2)
Height above Ground $z_{crit} + h_s$ Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0	Plume-averag (meters) above stack 22.92 39.41 69.89	ed Vertical V Plume Radius(m) 3.670 5.043 9.920	Z83.4 Velocities state Vert. Vel(m/s) 13.29 8.50 6.35	ring at en Plume Temp(K) 372.25 333.13		g ase: Brigg's Grad'PR 8.91 6.80 5.10	$\begin{split} &(6.25\text{D-z}_{v})^{2} - (\text{Va})_{o}^{3})/(4.3^{3}0.16^{3}) \\ &+ \text{http://www.1728.} \\ &\text{ives the real solution x = z-zv =} \\ & &\text{or z(m) =} \\ & &\text{z(ft) =} \\ & &\text{z(ft) =} \\ & &\text{VBargys} = (2/3) \times 1.6^{(0.22)} \times F^{(1/2)} \times u^{(1/2)} \times u^{$	01.48 109.3 358 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37	meters ed Vertical \(\text{Plume} \) Radius(m) 3.670 5.043 9.920 14.796	Z83.4 Velocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48	reting at en Plume Temp(K) 372.25 333.13 323.21		9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26	$\begin{array}{lll} (6.25D\text{-}z_{v})^{2} - (\text{Va})_{o}^{3})/(4.3^{3}0.16^{3}) \\ & & \text{http://www.1728.i} \\ \text{ives the real solution x = z-zv =} \\ & & \text{or } z(m) = \\ & & \text{cft}) = \\ & & \text{VB}_{\text{Begs}} = (2/3) \times 1.6^{(0.2)} \times F^{(1/2)} \times u^{(1/2)} \times u^{(1/2$	101.48 109.3 356 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85	ed Vertical V Plume Radius(m) 3.670 5.043 9.920 14.796 19.673	Z83.4 Velocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.96	reet Plume Temp(K) 372.25 333.13 323.21 319.17		g ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73	$\begin{array}{ll} (6.25D\text{-}z_{\text{Y}})^2 - (\text{Va})_o^3)/(4.3^30.16^3) = \\ & & \text{http://www.1728.i} \\ \text{ives the real solution } x = z - z v = \\ & & & & & \text{or } z(m) = \\ & & & & & & & \text{cr(f)} = \\ & & & & & & & \text{cr(f)} = \\ & & & & & & & \text{Valeges} = (2/3) \times 1.6^{322} \times \text{pt}^{1/23} \times \text$	101.48 109.3 356 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37	meters ed Vertical \(\text{Plume} \) Radius(m) 3.670 5.043 9.920 14.796	Z83.4 Velocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48	reet Plume Temp(K) 372.25 333.13 323.21 319.17		9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26	$\begin{array}{ll} (6.25D\text{-}z_{\text{Y}})^2 - (\text{Va})_o^3)/(4.3^30.16^3) = \\ & & \text{http://www.1728.i} \\ \text{ives the real solution } x = z - z v = \\ & & & & & \text{or } z(m) = \\ & & & & & & & \text{cr(f)} = \\ & & & & & & & \text{cr(f)} = \\ & & & & & & & \text{Valeges} = (2/3) \times 1.6^{322} \times \text{pt}^{1/23} \times \text$	101.48 109.3 356 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0	Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85	ed Vertical V Plume Radius(m) 3.670 5.043 9.920 14.796 19.673	Z83.4 Velocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.96	arting at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10		g ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73	$\begin{split} &(6.25D\text{-}z_{\text{y}})^{2} - (\text{Va})_{o}^{3})/(4.3^{3}0.16^{3}) \\ & \text{http://www.1728} \\ &\text{ives the real solution } x = z\text{-}z\text{v} = \\ & \text{or } z(m) = \\ & z(ft) = \\ & V_{\text{daggs}} = (2/3) \times 1.6^{(3/2)} \times f^{(1/2)} \times u^{1/2}) \\ & 0.50 \text{ m/s windspeed} \\ &\text{Spillane Equations:} \\ &V_{\text{plume}} = (V(w))_{o}^{3} \cdot 40.12F_{o}([z\cdot z_{o})^{2} \cdot (6.25D - a = 0.16(z\cdot z_{v})) \\ & \theta_{p} = \theta_{o} (1 + (1 - (\theta_{o}/\theta_{o}))^{*}(V_{\text{ext}}D^{2}/(4V_{e$	101.48 109.3 35 (z ^(-1/2)
Height above Ground $z_{crit} + h_s$ Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85	meters Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550	Z83.4 Velocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.96 4.59	arting at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10		9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36	$\begin{split} &(6.25D\text{-}z_{\text{y}})^{2} - (\text{Va})_{o}^{3})/(4.3^{3}0.16^{3}) \\ & \text{http://www.1728} \\ &\text{ives the real solution } x = z\text{-}z\text{v} = \\ & \text{or } z(m) = \\ & z(ft) = \\ & V_{\text{daggs}} = (2/3) \times 1.6^{(3/2)} \times f^{(1/2)} \times u^{1/2}) \\ & 0.50 \text{ m/s windspeed} \\ &\text{Spillane Equations:} \\ &V_{\text{plume}} = (V(w))_{o}^{3} \cdot 40.12F_{o}([z\cdot z_{o})^{2} \cdot (6.25D - a = 0.16(z\cdot z_{v})) \\ & \theta_{p} = \theta_{o} (1 + (1 - (\theta_{o}/\theta_{o}))^{*}(V_{\text{ext}}D^{2}/(4V_{e$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33	meters ed Vertical \ Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427	Z83.4 Velocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.96 4.59 4.32	rting at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89		9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36	$\begin{aligned} &(6.25\text{D-z}_{\text{V}})^2 - (\text{Va})_o^3)/(4.3^30.16^3) = \\ &\text{http://www.1728.} \\ &\text{ives the real solution } x = z - z v = \\ &\text{or } z(m) = \\ &\text{z(ft)} = \\ &\text{V}_{\text{Beggs}} = (2/3) \times 1.6^{3/2} \times f^{1/2} \times u^{1/2/2}, \\ &\text{0.50 m/s windspeed} \\ &\text{Spillane Equations:} \\ &\text{V}_{\text{plum}} = \{(\text{Va})_o^3 + 0.12F_o[(z - z_v)^2 - (6.25\text{D} - 20.16(z - z_v)) + (1.62\text{P/g}))^4 \times (V_{\text{exit}} D^2/(4\text{V} - 20.16\text{P/g}))^4 \times $	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81	meters ed Vertical V Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304	Z83.4 Velocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.96 4.59 4.32 4.10	rting at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 315.11	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 3.08 2.86	$\begin{aligned} &(6.25\text{D-z}_{v})^{2} - (\text{Va})_{o}^{3})/(4.3^{3}0.16^{3}) \\ & + \frac{\text{NtD} / \text{lwww. 1728.}}{\text{lives the real solution x = z-zv =}} \\ & \text{or z(m) =} \\ & \text{z(ft) =} \\ & \text{V}_{8 \text{reg/s}} = (2/3) \times 1.6^{(3/2)} \times f^{(1/2)} \times u^{(1/2)}, \\ & \text{0.50 m/s windspeed} \end{aligned}$ $\begin{aligned} & \text{Spillane Equations:} \\ & \text{V}_{\text{plum}} = f(\text{Va})_{o}^{3} + 0.12F_{o}[(z-z_{v})^{2} - (6.25\text{D-s}) - (6.25$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96	meters ed Vertical \ Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180	283.4 /elocities stat Vel(m/s) 13.29 8.50 6.35 5.48 4.96 4.59 4.32 4.10 4.06	rting at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 315.11	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 3.08 2.86 2.83	$\begin{aligned} &(6.25D\text{-}z_y)^2\text{-}(Va)_o^3)/(4.3^30.16^3) = \\ & & \text{http://www.1728.} \\ & \text{ives the real solution } x = z\text{-}zv = \\ & & \text{or } z(m) = \\ & & & \text{cr(f)} = \\ & & & \text{val} \\ & & & \text{o.50 m/s windspeed} \\ & & \text{Spillane Equations:} \\ & & & \text{Vplume}^2(Va)_o^3 *0.12F_s(z\cdot z_s)^2 \cdot (6.25D - a) = 0.16(z\cdot z_s) \\ & & & & \text{g.} \end{aligned}$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 Begin Merging (touch) = 818.6 900.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 262.77	meters ed Vertical V Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057	Zes.4. Velocities station Vert. Vel(m/s) 13.29 8.50 6.35 5.448 4.96 4.59 4.32 4.10 4.666 3.92 3.77	ring at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 315.11 315.00 314.58	d of jet pha	9 ase: Brigg's 6.80 5.10 4.26 3.73 3.36 3.08 2.86 2.83 2.68	$\begin{aligned} &(6.25D\text{-}z_{y})^{2} - (Va)_{o}^{3})/(4.3^{3}0.16^{3}) \\ &&\text{http://www.1728.} \\ &\text{ives the real solution } x = z\text{-}zy = \\ &&&\text{or } z(m) = \\ &&&&z(ft) = \\ &&&&&z(ft) = \\ &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1000.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73	meters ed Vertical \(\text{Plume} \) Radlus(m) \(3.670 \) 5.043 \(9.920 \) 14.796 \(19.673 \) 24.550 \(29.427 \) 34.304 \(35.211 \) 39.180 \(44.057 \) 48.934	Z83.4 Velocities stat Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.99 4.59 4.32 4.10 4.06 3.92 3.77 3.64	reting at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 315.11 315.00 314.80 313.92	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 2.86 2.83 2.68 2.54	$\begin{aligned} &(6.25D\text{-}z_{\text{y}})^{2} - (\text{Va})_{o}^{3})/(4.3^{3}0.16^{3}) \\ &&\text{http://www.1728.} \\ &\text{ives the real solution } x = z\text{-}z\text{y} = \\ &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1100.0 1200.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 263.25 313.73 344.21	meters ed Vertical \(^1\) Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.934 53.811	283.4 /elocities stat Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.996 4.59 4.32 4.10 4.06 3.92 3.777 3.64 3.52	ret feet ret ret ret ret ret ret ret ret ret	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.36 3.08 2.86 2.83 2.54 2.41	$\begin{aligned} &(6.25D\text{-}z_{\gamma})^{2} - (\text{Va})_{o}^{3})/(4.3^{3}0.16^{3}) \\ & + \text{http://www.1728.u} \end{aligned}$ ives the real solution $x = z\text{-}zy = 0$ or $z(m) = z(ft) = z(ft)$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1100.0 1200.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69	meters ed Vertical \ Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.657 48.934 53.811 58.688	283.4 /elocities state Vert. Vel(m/s) 8.50 6.35 5.48 4.96 4.59 4.32 4.10 4.06 3.92 3.77 3.64 3.52 3.42	rting at en Plume Temp(K) 372.25 333.13 323.21 319.17 10 315.89 315.11 315.00 314.58 314.20 313.92 313.70 313.63	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 3.08 2.86 2.83 2.68 2.54 2.41 2.30 2.20	$ (6.25D-z_{\rm V})^2 - (Va)_o^3)/(4.3^30.16^3) = \frac{http://www.1728.u}{http://www.1728.u} $ ives the real solution $x=z-zv=0$ or $z(m)=z(t)=z(t)=y_{0rgys}=(2/3) x 1.6^{3/2} x f^{1/2} y t^{1/2/2} y t^{1/2/2} = 0.50 \text{ m/s windspeed} $ Spillane Equations: $V_{plum} = \{(Va)_o^3 + 0.12F_a[(z-z_v)^2 - (6.25D-a = 0.16(z-z_v)) = 0.56(z-z_v) = 0$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1100.0 1200.0 1300.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17	meters ed Vertical \ Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.934 53.811 58.688	283.4 Velocities stat Vel(m/s) 13.29 8.50 6.35 5.48 4.96 4.55 4.32 4.10 4.06 3.92 3.77 3.62 3.42 3.342	rting at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 315.11 315.00 314.58 314.20 313.92 313.70 313.53	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 2.86 2.83 2.68 2.54 2.30 2.20 2.12	$\begin{aligned} &(6.25D\text{-}z_y)^2\text{-}(Va)_o^3)/(4.3^30.16^3) = \\ & & \text{http://www.1728.} \\ & \text{ives the real solution } x = z\text{-}zv = \\ & & \text{or } z(m) = \\ & & & \text{cr(f)} = \\ & & & \text{val} \\ & & & \text{loss} \\ & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & \text{sec} \\ & & & & & & & & \text{sec} \\ & & & & & & & & \text{sec} \\ & & & & & & & & \text{sec} \\ & & & & & & & & \text{sec} \\ & & & & & & & & \text{sec} \\ & & & & & & & & & \text{sec} \\ & & & & & & & & & \text{sec} \\ & & & & & & & & & & \text{sec} \\ & & & & & & & & & & & \text{sec} \\ & & & & & & & & & & & & & \\ & & & & $	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1000.0 1100.0 1200.0 1300.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17	meters ed Vertical V Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.934 53.811 58.688 63.564 68.441	Zes.4. Velocities station Vert. Vel(m/s) 13.29 8.50 6.35 5.44 4.96 4.59 4.32 4.10 4.66 3.92 3.77 3.64 3.52 3.42 3.33 3.25	ring at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 314.58 314.20 313.92 313.70 313.53 313.39 313.28	d of jet pha	9 ase: Brigg's 8.91 6.80 5.10 4.266 3.73 3.36 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12	$\begin{aligned} &(6.25D\text{-}z_y)^2\text{-}(Va)_o^3)/(4.3^30.16^3) = \\ & & \text{http://www.1728.i} \\ &\text{ives the real solution } x = z\text{-}zv = \\ & & & & & & & & & & & & & \\ & & & &$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1000.0 1100.0 1200.0 1400.0 1400.0 1500.0 End Merging (full/mp) = 1540.6	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17 435.65	meters ed Vertical \(\text{Plume} \) Radlus(m) \(3.670 \) 5.043 \(9.920 \) 14.796 \(19.673 \) 24.550 \(29.427 \) 34.304 \(35.211 \) 39.180 \(44.057 \) 48.934 \(53.811 \) 58.686 \(68.441 \) 70.421	Z83.4 Velocities stat Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.99 4.59 4.32 4.10 4.06 3.92 3.77 3.64 3.52 3.42 3.33 3.25 3.22	ring at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 315.11 315.00 314.80 313.92 313.70 313.53 313.39 313.28	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12 2.04	$\begin{aligned} &(6.25D\text{-}z_{\text{y}})^{2} - (\text{Va})_{o}^{3})/(4.3^{3}0.16^{3}) \\ &&\text{http://www.1728} \\ &\text{ives the real solution } x = z\text{-}z\text{y} = \\ &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1540.6	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.03	meters ed Vertical \(\text{Plume} \) Radius(m) \(3.670 \) 5.043 \(9.920 \) 14.796 \(19.673 \) 24.550 \(29.427 \) 34.304 \(35.211 \) 39.180 \(44.057 \) 48.934 \(53.811 \) 58.688 \(63.564 \) 68.4411 \(70.421 \) 73.318	283.4 /elocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.99 4.32 4.10 4.06 3.52 3.42 3.33 3.252 3.18	ring at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 315.11 315.00 313.92 313.70 313.53 313.24 313.19	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12 2.04 2.02	$ (6.25D-z_{\rm V})^2 - (Va)_o^3)/(4.3^30.16^3) = \frac{http://www.1728.1}{http://www.1728.1} $ ives the real solution $x=z-zv=0$ or $z(m)=z(ft$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1540.6	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.03 466.13	meters ed Vertical \ Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.934 53.811 58.688 63.564 68.411 70.421 73.318 78.195	283.4 /elocities stat Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.996 4.59 4.32 4.10 4.06 3.92 3.3777 3.64 3.52 3.42 3.33 3.25 3.22 3.18	rting at en Plume Temp(K) 372.25 333.13 323.21 315.10 315.89 315.11 315.00 314.58 314.20 313.92 313.70 313.63 313.28 313.284 313.19 313.11	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.36 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12 2.04 2.02 1.98 1.92	$ (6.25D-z_{\rm V})^2 - (Va)_o^3)/(4.3^30.16^3) = \frac{http://www.1728.u}{http://www.1728.u} $ ives the real solution $x=z-zv=0$ or $z(m)=z(ft$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1540.6	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.03	meters ed Vertical \(\text{Plume} \) Radius(m) \(3.670 \) 5.043 \(9.920 \) 14.796 \(19.673 \) 24.550 \(29.427 \) 34.304 \(35.211 \) 39.180 \(44.057 \) 48.934 \(53.811 \) 58.688 \(63.564 \) 68.4411 \(70.421 \) 73.318	283.4 /elocities stat Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.956 4.59 4.32 4.10 4.06 3.92 3.377 3.64 3.52 3.42 3.33 3.25 3.22 3.18	rting at en Plume Temp(K) 372.25 333.13 323.21 315.10 315.89 315.11 315.00 314.58 314.20 313.92 313.70 313.63 313.28 313.284 313.19 313.11	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12 2.04 2.02	$ (6.25D-z_{\rm V})^2 - (Va)_o^3)/(4.3^30.16^3) = \frac{http://www.1728.u}{http://www.1728.u} $ ives the real solution $x=z-zv=0$ or $z(m)=z(ft$	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1540.6	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.03 466.13	meters ed Vertical \ Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.934 53.811 58.688 63.564 68.411 70.421 73.318 78.195	283.4 /elocities stat Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.996 4.59 4.32 4.10 4.06 3.92 3.3777 3.64 3.52 3.42 3.33 3.25 3.22 3.18	ring at en Plume Temp(K) 372.25 333.13 323.21 319.17 10 315.89 315.11 315.00 314.58 314.20 313.93 313.39 313.28 313.24 313.19 313.11	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.36 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12 2.04 2.02 1.98 1.92	(6.25D-z _v) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728.ives the real solution x = z-zv = or z(m) =	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1000.0 1100.0 1200.0 1300.0 End Merging (full/mp) = 1540.6 1600.0 End Merging (full/mp) = 1540.6	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17 445.65 448.03 466.13 496.61	meters ed Vertical V Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.934 53.811 58.688 63.564 68.441 70.421 73.318 78.195 83.072	Zes.4. Velocities station Vert. Vel(m/s) 13.29 8.50 6.55 5.44 4.96 4.59 4.32 4.10 4.66 3.92 3.77 3.64 3.52 3.42 3.33 3.25 3.22 3.118 3.111 3.05	ring at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 314.58 314.20 313.92 313.70 313.39 313.28 313.24 313.19 313.19 313.19	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 2.86 2.83 2.68 2.54 2.31 2.30 2.20 2.12 2.04 1.98 1.92 1.86	(6.25D-z _Y) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728.ives the real solution x = z-zy =	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 800.0 800.0 800.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1540.6 1600.0 1700.0 1800.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 435.65 448.03 466.13 496.61 527.09 557.57	meters ed Vertical V Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.934 53.811 58.688 63.564 68.441 70.421 73.318 78.195 83.072 87.948	283.4 /elocities stat	ring at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 315.11 315.00 313.92 313.70 313.93 313.28 313.29 313.11 313.05 312.99	d of jet pho	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12 2.04 2.02 1.98 1.92 1.86 1.81	$ (6.25D-z_{\rm y})^2 - (Va)_o^3)/(4.3^30.16^3) = \frac{http://www.1728.1}{http://www.1728.1} $	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1000.0 1100.0 1200.0 1300.0 End Merging (full/mp) = 1540.6 1600.0 1700.0 1800.0 1800.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.03 466.13 496.61 527.09 557.57 588.05	meters ed Vertical \(\text{Plume} \) Radlus(m) \(3.670 \) 5.043 \(9.920 \) 14.796 \(19.673 \) 24.550 \(29.427 \) 34.304 \(35.211 \) 39.180 \(44.057 \) 48.934 \(53.811 \) 58.686 \(68.441 \) 70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 73.318 \(70.421 \) 74.348 \(70.421 \) 75.348 \(70.421 \) 76.348 \(70.421 \) 77.348 \(70.421 \) 78.348 \(70.421 \) 78.348 \(70.421 \)	283.4 /elocities stat	ring at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 314.52 313.92 313.70 313.39 313.24 313.11 313.05 312.94 312.86	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.266 3.73 3.36 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12 2.04 2.02 1.98 1.92 1.86 6.1.81	$ (6.25D-z_{\rm V})^2 - (Va)_o^3)/(4.3^30.16^3) = \frac{http://www.1728.1}{http://www.1728.1} $	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1100.0 1200.0 1300.0 1400.0 End Merging (full/mp) = 1540.6 1600.0 1700.0 1800.0 2000.0 2000.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 263.25 313.73 344.21 374.69 405.17 435.65 448.03 466.13 496.61 527.09 557.57 588.05 649.01 709.97	meters ed Vertical \(^1\) Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.934 53.811 58.688 63.564 68.4411 70.421 73.318 78.195 83.072 87.948 92.825 102.579 112.332	283.4 /elocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.99 4.32 4.10 4.06 3.52 3.42 3.33 3.42 3.31 3.11 3.05 2.99 2.94 2.84	ring at en Plume Temp(K) 372.25 333.13 323.21 317.10 315.89 315.11 315.00 314.52 313.70 313.53 313.29 313.24 313.11 313.05 312.99 312.86 312.80	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.37 3.36 2.86 2.84 2.41 2.30 2.20 2.12 2.04 2.02 1.98 1.92 1.86 1.81 1.76 1.68	(6.25D-z _v) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728.ives the real solution x = z-z _v = or z(m) = c(ft) = V _{Bags} = (2/3) x 1.6 ^(3/2) x F ^(1/2) x u ^(1/2) y 0.50 m/s windspeed Spillane Equations: V _{plum} ={(Va) _o ³ -0.12F _o {(z-z _o) ² -(6.25D-a=0.16(z-z _o))*(V _{ext} D ² /(4V) θ _p =θ _s (1+(1-(θ _e /θ _s))*(V _{ext} D ² /(4V)	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 600.0 700.0 800.0 800.0 Begin Merging (touch) = 818.6 900.0 1000.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1540.6 1600.0 1700.0 1800.0 1700.0 2000.0 2200.0 2400.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.03 466.13 496.61 527.09 557.57 588.05 649.01 709.97	meters ed Vertical \ Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.957 48.957 48.957 47.3318 78.195 83.072 87.948 92.25 102.579 112.332	283.4 /elocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.996 4.59 4.32 4.10 4.06 3.92 3.342 3.33 3.25 3.24 3.33 3.25 3.22 3.18 3.11 3.05 2.99 2.94 2.284	rting at en Plume Temp(K) 372.25 333.13 323.21 315.10 315.89 315.11 315.00 314.58 314.20 313.92 313.70 313.53 313.28 313.24 313.19 313.11 313.05 312.94 312.80 312.80	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.36 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12 2.04 2.02 2.18 1.98 1.92 1.86 1.60 1.54	(6.25D-z _v) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728.ives the real solution x = z-zv = or z(m) =	101.48 109.3 35 (z ^(-1/2)
Height above Ground $z_{crit} + h_s$ able of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1000.0 1100.0 1200.0 1400.0 550.0 1500.0 1700.0 1800.0 1900.0 1800.0 2000.0 2000.0 2400.0 2400.0 2600.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 262.77 283.25 313.73 344.21 374.69 406.13 496.61 527.09 557.57 588.05 649.01 709.97 770.93 831.89	meters ed Vertical V Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.934 53.811 58.688 63.564 68.441 70.421 73.318 78.195 83.072 87.948 92.825 102.579 112.332 122.086 131.840	Z83.4 Velocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.96 4.59 4.32 3.177 3.64 3.52 3.22 3.18 3.05 2.99 2.94 2.84 2.75 2.68	ring at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 314.58 314.20 313.92 313.70 313.39 313.28 313.24 313.19 313.11 313.05 312.99 312.94 312.86 312.86 312.75	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.266 3.73 3.36 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12 2.04 2.02 1.98 1.92 1.86 1.81 1.76 1.68 1.60 1.54	(6.25D-z _Y) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728.ives the real solution x = z-zv =	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1000.0 1100.0 1200.0 1300.0 End Merging (full/mp) = 1540.6 1600.0 1700.0 1800.0 2000.0 2000.0 2200.0 2200.0 2600.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.03 466.13 496.61 527.09 557.57 588.05 649.01 709.97 7770.93 831.89	meters ed Vertical \(\text{Plume} \) Radlus(m) \(3.670 \) 5.043 \(9.920 \) 14.796 \(19.673 \) 24.550 \(29.427 \) 35.211 \(39.180 \) 44.057 \(48.934 \) 53.811 \(58.688 \) 63.5684 \(68.441 \) 70.421 \) 73.318 \(70.421 \) 73.918 \(92.825 \) 102.579 \) 112.336 \(12.336 \) 121.2086 \(131.840 \) 141.593	283.4 /elocities stat Vert. Vel(m/s) 13.29 8.50 6.35 6.348 4.99 4.59 4.32 4.10 4.06 3.92 3.77 3.64 3.55 3.22 3.18 3.11 3.05 2.99 2.94 2.84 2.75 2.686 2.61	ring at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 314.20 313.92 313.93 313.23 313.23 313.24 313.11 313.05 312.26 312.80 312.80 312.75 312.71	d of jet pho	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.266 3.73 3.36 3.08 2.86 2.54 2.41 2.30 2.20 2.12 2.04 2.02 1.98 1.92 1.168 1.81 1.76 1.68 1.60 1.54 1.48	$ (6.25D-z_y)^2 - (Va)_o^3)/(4.3^30.16^3) = \frac{http://www.1728.1}{http://www.1728.1} $	01.48 109.3 358 (z ^(-1/2)
Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1540.6 1600.0 1700.0 1800.0 2000.0 2200.0 2400.0 2800.0 3800.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 263.25 313.73 344.21 374.69 405.17 435.65 448.03 466.13 496.61 527.09 557.57 588.05 649.01 709.97 770.93 831.89 892.85	meters ed Vertical \(\text{Plume} \) Radlus(m) \(3.670 \) 5.043 \(9.920 \) 14.796 \(19.673 \) 24.550 \(29.427 \) 34.304 \(35.211 \) 39.180 \(44.057 \) 48.934 \(53.811 \) 58.817 \(58.688 \) 68.544 \(68.441 \) 70.421 \) 73.318 \(78.195 \) 83.072 \(87.948 \) 92.825 \(102.579 \) 112.332 \(12.086 \) 131.840 \(141.593 \) 165.977	283.4 /elocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.99 6.4.59 4.32 4.10 4.06 3.92 3.77 3.64 3.52 3.12 3.11 3.05 2.99 2.94 2.84 2.75 2.68 2.61 2.555	ring at en Plume Temp(K) 372.25 333.13 323.21 319.17 317.10 315.89 315.11 315.00 313.92 313.70 313.53 313.24 313.19 313.10 312.86 312.86 312.86 312.62	d of jet pho	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 3.08 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12 2.04 1.98 1.92 1.86 1.81 1.76 1.68 1.60 1.54 1.43 1.43	(6.25D-z _V) ² -(Va) _o ³)/(4.3 ³ 0.16 ³)= http://www.1728.ives the real solution x = z-zv =	01.48 109.3 358 (z ^(-1/2)
Height above Ground z _{crit} +h _s Table of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1100.0 1200.0 1300.0 1400.0 End Merging (full/mp) = 1540.6 1600.0 1700.0 1800.0 2000.0 2000.0 2000.0 2400.0 2800.0 2800.0 2800.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 283.25 313.73 344.21 374.69 405.17 435.65 448.03 466.13 496.61 527.09 575.57 588.05 649.01 709.97 770.93 831.89 882.85 1045.25 1197.65	meters ed Vertical \(^1\) Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.934 53.811 58.688 63.564 68.4411 70.421 73.318 78.195 83.072 87.948 92.825 102.579 112.332 122.086 131.840 141.593 165.977 190.361	283.4 /elocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.99 4.32 4.10 4.06 3.52 3.42 3.33 3.252 3.18 3.11 3.05 2.94 2.84 2.75 2.68 2.61 2.555 2.42 2.31	ring at en Plume Temp(K) 372.25 333.13 323.21 317.10 315.89 315.11 315.00 313.92 313.70 313.53 313.24 313.19 313.11 313.05 312.99 312.94 312.86 312.80 312.75 312.80 312.62 312.62	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 2.86 2.83 2.686 2.54 2.41 2.30 2.20 2.12 2.04 2.02 1.98 1.92 1.86 1.81 1.76 1.68 1.81 1.43 1.43 1.32 1.23	(6.25D-z _v) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728.ives the real solution x = z-z _v =	101.48 109.3 35 (z ^(-1/2)
Height above Ground z _{crit} +h _s Fable of Plume Top-Hat Diameters (2a) and F Height (feet) above ground Top of jet = 145.9 200.0 300.0 400.0 500.0 600.0 700.0 800.0 Begin Merging (touch) = 818.6 900.0 1100.0 1200.0 1300.0 1400.0 1500.0 End Merging (full/mp) = 1540.6 1600.0 1700.0 1800.0 2000.0 2200.0 2400.0 2800.0 3800.0	86.389 Plume-averag (meters) above stack 22.92 39.41 69.89 100.37 130.85 161.33 191.81 222.29 227.96 252.77 263.25 313.73 344.21 374.69 405.17 435.65 448.03 466.13 496.61 527.09 557.57 588.05 649.01 709.97 770.93 831.89 892.85	meters ed Vertical \ Plume Radius(m) 3.670 5.043 9.920 14.796 19.673 24.550 29.427 34.304 35.211 39.180 44.057 48.934 53.811 58.688 63.564 68.4411 70.421 73.318 78.195 83.072 87.948 92.825 102.579 112.332 122.086 131.840 141.593 165.977 190.361 214.745	283.4 /elocities state Vert. Vel(m/s) 13.29 8.50 6.35 5.48 4.99 6.4.59 4.32 4.10 4.06 3.92 3.77 3.64 3.52 3.12 3.11 3.05 2.99 2.94 2.84 2.75 2.68 2.61 2.555	riting at en Plume Temp(K) 372.25 333.13 323.21 317.10 315.89 315.11 315.00 314.58 314.20 313.92 313.70 313.53 313.24 313.19 313.11 313.05 312.99 312.26 312.80 312.75 312.71 312.68 312.66 312.80 312.75 312.71	d of jet pha	9 ase: Brigg's Grad'PR 8.91 6.80 5.10 4.26 3.73 3.36 3.08 2.86 2.83 2.68 2.54 2.41 2.30 2.20 2.12 2.04 1.98 1.92 1.86 1.81 1.76 1.68 1.60 1.54 1.43 1.43	(6.25D-z _v) ² -(Va) _o ³]/(4.3 ³ 0.16 ³)= http://www.1728.ives the real solution x = z-zv = or z(m) =	01.48 109.3 358 (z ^(-1/2)



		fety and Bu			" Colu: O:	diday ·	laviana Haladat - !- d f*	
	" The Evalua						/arious Heights in the Merg ueensland, Australia," Dr. H	
Ambient Conditions:		riume noi	II I WO Gas-Iu	ibine rowe			eutral conditions (d0/dz=0 or	
Ambient Potential Temp θ _a	312.43	Kelvins	102.7	°F	Conocanto		meters/feet	oa oe)
Plume Exit Conditions:					Gravity g	9.81	m/s ²	
Stack Height h _s	21.549	meters	70.7	feet	λ	1.11		
Stack Diameter D	3.6698	meters	12.0	feet	λο	~1.0		
Number of Stacks N	2						e plume treatment in Peter Be	
Average Adjacent Stack Separation d		meters	231.04				sed by N ^{0.25} at the height whe	
Stack Velocity V _{exit} Volumetric Flow	26.579	m/s cu.m/sec	595,689	ft/sec	πV _{exit} D ² /4	d (interp. be	low ht, single merged stack a	
Stack Potential Temp θ_s		Kelvins	848		πv _{exit} D /4			Sect.2/¶1
Initial Stack Buoyancy Flux Fo	500.25		040		αV _{ανι} ,D ² (1-6	l _o /θ _o)/4 = V	ol.Flow(g/ π)(1- θ_a/θ_s)	Sect.2/¶1
Plume Buoyancy Flux F		m4/s3			-		,θ _p at plume height (see belo	
Conditions at End (Top) of Jet Phase:					,			
Height above Stack z _{jet}	22.936	meters*	75.3	feet*	z _{jet} = 6.250	, meters*=	meters above stack top	Sect.3/¶1
Height above Ground z _{jet} +h _s		meters	145.9					
Vertical Velocity V _{jet}	13.290			ft/sec	V _{jet} = 0.5V _e	exit = V _{exit} /2		
Plume Top-Hat Diameter 2a _{jet}	7.340	meters	24.1	feet	2a _{jet} = 2D		Conservation of momentum	
Spillane Methodology - Analytical Solutions	for Calm Con	ditions for	Plume Height	e above le	at and Mero	ing Phace		
Single Plume-averaged Vertical Velocity								
Single Plume Values: Plume Top-Hat Radius a		-	e Merging On				r increase with height	Sect.2/Eq.6
Virtual Source Height z _v		meters*		feet*			, meters*=meters above stack top	
Height above Ground z _v +h _s		meters		feet			where $(\theta_a/\theta_s)^{1/2} = (\theta_e/\theta_s)^{1/2} =$	
Single Plume Values: Vertical Velocity V	Use	d in Plume	Merging On	у			,) ² - (6.25D-z _v) ²]) ^(1/3) / a	Sect.2.1(6)
Product (Va) _o	31.986	m²/s			V _{exit} (D/2)(θ	$(\theta_s)^{1/2}$		
Plume Merging - Based on Single Plume Cal				foot	20		2)	Sect.3/¶3
Begin Merging Plume Top-Hat Diameter 2a _{touch} Height above Stack z _{touch}	70.420 227.956	meters*	231.0 747.9		2a _{touch} =d, (meters*=meters above stack 	ton
Height above Stack z _{touch}	249.505		747.9 818.6		∠touch = Z _V +	w(∠ U.10),	moters =meters above stack	ιορ
Vertical Velocity V _{touch}	4.062			ft/sec	V _{touch} = {(V	a) _o 3 + 0.12	F _o [(z-z _v) ² - (6.25D-z _v) ²]} ^(1/3)	/ a
Total Merging Plume Top-Hat Diameter 2a _{full}	140.840	meters	462.1				all=d(N-1)/2) FOR 2 STACKS,	
Height above Stack z _{full}	448.018		1469.9	feet*			meters*=meters above stack	
Height above Ground z _{full} +h _s	469.567	meters	1540.6	feet				
Vertical Velocity V _{full}	3.219		10.6	ft/sec	V _{full} = {(Va)	6 ³ + 0.12F ₀	$[(z_{full}-z_v)^2 - (6.25D-z_v)^2]$	/ a _{full}
Product (V ³ a) _{full}		m ⁴ /s ³						
Conditions at End (Top) of Merging Phase - D				ed Plume o				
Merged Plume Values: Plume Diameter 2a			Table Below	f t			z _{full})), or linear increase with l here Total Merging Occurs	neight
Revised Merged Plume Radius a _m Revised Merged Plume Velocity V _m	3.828	meters	274.8	ft/sec			where Total Merging Occurs	
Revised Virtual Source Height z _{full}		meters*	1469.9				ere Total Merging Occurs (sh	iown above)
Revised Vertical Velocity V			Tables Below	,			eights above total merging el	
							z-z _{touch})/(z _{full} -z _{touch})	
Multiple Plume Calculations							for heights below total mergi	ng elevation
Solve for plume-averaged vertical veloc	-	1,000.0			meters abo			
Gives the following Height above Stack z	283.251		929.3				MERGING PHASE-INTERPO	LATE
Plume Top-Hat Radius a		meters	#N/A	ft/sec	a=a _m +0.16 V={N(V ³ a) _f			
Vertical Velocity V	4.003	m/s	13.13	π/sec		,	'Z _{full} z'-Z _{touch})/(Z _{full} -Z _{touch}) if Z_{touch} •	
							if z <z<sub>touch (Zfull*Ztouch) ii Ztouch</z<sub>	Z~Zfull
Solve for Height of CASC critical vertical	velocity V _{crit}	5.30	m/s		BEFORE T		in 2 -2 touch	
Find Height above Stack z _{crit}	SINGLE		SINGLE	feet			/(V _{crit}) ³]-a _m }/0.16 if V _{crit} <v<sub>m</v<sub>	
Height above Ground z _{crit} +h _s	SINGLE	meters	SINGLE	feet	z _{crit} =z _{touch} +	(Zfull-Ztouch)	*(V _{crit} -V _{touch})/(V _m -V _{touch}) if V _c	rit>V _m
Table of Plume-averaged Vertical Velocities:								
Height (feet)	(meters)	Plume	Vert.					
above ground					Cinal - Di	Fa::-		
Top of jet = 145.9	22.92	5.042	13.29		Single Plur)2 (6.25D z)211 ^{1/3} / a	
200.0 300.0	39.41 69.89	5.043 9.920			$v_{plume} = \{(va)_o \\ a = 0.16(z - 10) \}$		_v) ² -(6.25D-z _v) ²]} ^{1/3} / a	
400.0	100.37	14.796					$_{xit}D^2/(4V_{plume}*a^2*\lambda^2)))$	
500.0	130.85	19.673			-p -s((1	es// (* e	An (· · prome a / ///	
600.0	161.33	24.550						
700.0	191.81	29.427	4.32					
800.0	222.29	34.304	4.10					
Begin Merging (touch) = 818.6	227.96	35.210	4.06		Interpolated			
900.0	252.77	#N/A	4.04		V'=V _{touch} +(V _m -V _{touch})*(z'-z _{touch})/(z _{full} -z _{touch})	
1000.0	283.25	#N/A	4.00		-			
1100.0	313.73 344.21	#N/A						
1200.0 1300.0	344.21 374.69	#N/A #N/A	3.94		-			
1300.0	405.17	#N/A			-			
1500.0	435.65	#N/A	3.84					
End Merging (full/mp) = 1540.6	448.03	83.744	3.83		Merged Plu	me Eqns		
1600.0	466.13	86.642			V={N(V ³ a) _f			
1700.0	496.61	91.519			a=a _m +0.16			
1800.0	527.09	96.396	3.65					
1900.0	557.57	101.272						
2000.0	588.05	106.149						
2200.0	649.01	115.903						
2400.0	709.97	125.656						
2600.0	770.93	135.410						
2800.0	831.89	145.164						
3000.0	892.85	154.917	3.12					
3500.0	1045.25	179.301	2.97					
4000.0 4500.0	1197.65 1350.05	203.685 228.069						
÷500.0								
5000.0	1502.45	252.453	2.65					



5.15 Water Resources

19. Wastewater Discharge - Appendix B (g) (14) (C) (8)

For all projects which have a discharge, provide a copy of the will-serve letter, permit or contract with the public or private entity that will be accepting the wastewater and contact storm water from the project. The letter, permit or contract, if possible, shall identify the discharge volumes and the chemical or physical characteristics under which the wastewater and contact storm water will be accepted.

In the event that a will-serve letter, permit, or contract cannot be provided, identify the most likely wastewater/storm water entity and discuss why the applicant was unable to secure the necessary assurances to serve the project's wastewater/storm water needs. Also, discuss the term of the wastewater service to the project, whether the wastewater entity has adequate permit capacity for the volume of wastewater from the project and has adequate permit levels for the chemical/physical characteristics of the project's wastewater and storm water for the life of the project, and any issues or conditions/restrictions the wastewater entity may impose on the project....

Information required to make AFC conform with regulations:

Please provide information demonstrating how the applicant will comply with the discharge restrictions stated in the provided will-take letter. If the restrictions cannot be accommodated, the applicant should provide alternative discharge options.

Response: The will-take letter describes a wastewater discharge prohibition during peak sewer-flow hours. A sewer flow-study is scheduled, and will determine any restricted hours for sewer reaches downstream of SERC's interconnection point. The flow-study will allow the City to specify times of day when SERC's wastewater discharge would exceed the City's sewer conveyance capacity. SERC is capable of complying with City discharge limits by operating the reverse osmosis (RO) system only during non-discharge-prohibited hours. This capability is enabled by SERC's demineralized water storage design which, even for maximum water-use hours, allows at least 12 hours of full-load operation without any operation of the RO or discharge of wastewater, which is sufficient to avoid curtailment. There will be no need to identify an alternative discharge approach.

20. Design Storm - Appendix B (g) (14) (D) (ii)

Drainage facilities and the design criteria used for the plant site and ancillary facilities, including but not limited to capacity of designed system, design storm, and estimated runoff;

Information required to make AFC conform with regulations:

Please provide a description of the design storm, type of system and methods that will be used to manage stormwater and the system capacity. Please also provide a description of the source control methods and systems that will be used to achieve Low Impact Development requirements.

Response: Attachment DA5.15-2, the completed drainage design study, addresses this topic.

21. Assumptions and Calculations - Appendix B (g) (14) (D) (iii)

All assumptions and calculations used to calculate runoff and to estimate changes in flow rates between pre- and post construction...

Information required to make AFC conform with regulations:

Please provide estimates and all assumptions used to calculate runoff volumes. Also include estimated changes in flow rates between pre- and post-construction

Response: Attachment DA5.15-2, the completed drainage design study, addresses this topic.

22. Regional and Local Requirements - Appendix B (g) (14) (D) (iii)

A copy of applicable regional and local requirements regulating the drainage systems, and a discussion of how the project's drainage design complies with these requirements.

Information required to make AFC conform with regulations:

Please provide a copy of applicable regional and local requirements regulating the drainage systems, and a discussion of how the project's drainage design complies with these requirements

Response: Attachment DA5.15-2, the completed drainage design study, addresses this topic.

23. Water Supply - Appendix B (g) (14) (D) (iii)

The effects of project demand on the water supply and other users of this source, including, but not limited to, water availability for other uses during construction or after the power plant begins operation, consistency of the water use with applicable RWQCB basin plans or other applicable resource management plans, and any changes in the physical or chemical conditions of existing water supplies as a result of water use by the power plant...

Information required to make AFC conform with regulations:

Please provide information about the effects of project demand on the water supply and other water users, including, but not limited to, water availability for other uses during construction and after the power plant begins operation.

Response: Information about the availability of local water supply is found primarily in Golden State Water Company's Urban Water Management Plan (UWMP) for the West Orange system (cited in the AFC as Golden State Water Company, 2016). The UWMP describes the sources of water to the West Orange system as primarily groundwater from the Orange County Groundwater Basin and surface water from the regional wholesale water supplier (Metropolitan Water District of Southern California [MWD], via the local wholesaler Municipal Water District of Orange County [MWDOC]). Approximately 90 percent of the current West Orange supply is from groundwater, and Golden State Water Company expects that percentage to remain generally the same in the future (GSWC, 2016). With regard to the groundwater basin, the UWMP describes basin management by the Orange County Water District (OCWD) and states that OCWD is designated as the local groundwater sustainability agency by the recently adopted Sustainable Groundwater Management Act.

Based on information presented in the UWMP about the groundwater and surface water sources, Golden State Water Company then describes water supply reliability in normal, single-dry, and multiple-dry years. UWMP Tables 7-2, 7-3, and 7-4 show that demand is available to meet supply in all year types. As source material for its conclusions, Golden State Water Company cites the OCWD Groundwater Management Plan and higher-tier UWMP documents prepared by MWD and MWDOC.

SERC demands are small in relation to the overall supplies available and described in the UWMP. For example, SERC operational water demands of 34 acre-feet per year are approximately 0.19 percent of the water supplies expected to be available in 2040 (17,701 acre-feet). Construction water demands are expected to be similar—preliminary estimates indicate that construction will require a total of approximately 30 acre-feet during the 14-month construction period. This is approximately 0.18 percent of the water supplies expected to be available in 2020 (16,722 acre-feet). This indicates that SERC water

use will have a negligible effect on the availability of water for other users during construction and operation.

Attachment DA5.15-1 Orange County Sanitation District Letter



ORANGE COUNTY SANITATION DISTRICT SEWER CAPACITY VERIFICATION

Date: December 7, 2016

Property Owner's Name: Stanton Energy Reliability Center (SERC), LLC

Property Address: 10711 Dale Avenue, Stanton CA 90680

Assessor Parcel No.: 126-531-43

In preparation for the development of the subject address, Gary Franzen of Wellhead Electric Company, requested a Will Serve Letter from the Orange County Sanitation District (Sanitation District) on behalf of Stanton Energy Reliability Center, LLC. The Sanitation District is not the local sewer service provider for the areas surrounding the subject property and does not permit direct connections by private developments to its regional sewer system. Since Will Serve letters are typically issued by the Sanitation District providing a direct connection to its local sewer system, the Sanitation District is willing to provide this letter instead to verify the Sanitation District has sufficient capacity in its regional sewers and treatment plants to service the subject address, given the flow data below provided by Mr. Franzen. This Verification Letter is given for information only and is not an approval to directly connect to a Sanitation District sewer.

The Sanitation District has studied the impacts of SERC's estimated wastewater discharge rates and annual quantities as follows:

- 1. Peak Discharge Rate = 54 gallons per minute
- 2. Average Daily Discharge = 8,767 GPD
- 3. Annual Quantities = 3.2 million gallons.

I hereby certify that the Sanitation District has sufficient treatment capacity in its facilities to accept the provided, estimated wastewater flows from the SERC, as conveyed to the Sanitation District by the City of Stanton, via the City of Stanton's municipal sanitary sewer system. When Sanitation District Capital Facilities Capacity Charges are paid to the City of Stanton, this property will be subject to the design and construction of any necessary on-site collection facilities and the discharge of wastewater from the property will not result in a violation of the Sanitation District's Regional Water Quality Control Board permit requirements. The Sanitation District would like to reevaluate the impacts to Sanitation District facilities if the quantity and/or quality of discharge changes from the estimates.



ORANGE COUNTY SANITATION DISTRICT SEWER CAPACITY VERIFICATION

Stanton Energy Reliability Center (SERC), LLC Page 2 December 7, 2016

If you have any questions, please contact Rudy Davila at (714) 593-7348.

Rudy Davila, P.E.

Engineer

Orange County Sanitation District/Planning Division

Attachment DA5.15-2 Drainage Design Study

Preliminary Hydrology and Drainage Study For Stanton Energy Reliability Center

Located within the Santa Ana River Watershed in Stanton California

December 2016



75 Arlington Street, 9th Floor Boston MA 02116



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Appendix D	Preliminary Geotechnical Investigation Report Excerpt
Appendix E	National Resources Conservation Service Technical Release 55 Table 2.2
Appendix F	Existing System AES Model Files
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Appendix H	Proposed System AES Model Files
Appendix I	Pump Station Sizing Criteria
Appendix J	Orange County Hydrology Manual
Appendix K	SERC Stanton Storm Channel Hydraulic Technical Memorandum
Appendix L	Hydrology Maps of Existing and Proposed Systems



Section 1 Executive Summary

The Stanton Energy Reliability Center (SERC) site is located within the Santa Ana River watershed, which covers approximately 2,800 square miles (SAWPA, 2012). The Santa Ana River's headwaters are located in the San Bernardino Mountains, with the river travelling approximately 96 miles before reaching its confluence with the Pacific Ocean. The site itself drains to the Stanton Storm Channel, part of the Orange County Bolsa Chica drainage system.

The objective of this study was to evaluate the existing and proposed drainage characteristics of the site, and develop a site grading and drainage design for the SERC Project that complies with all applicable laws, ordinances, regulations and standards. The Orange County Environmental Management Agency requires all drainage plans to demonstrate compliance with the 100-year flood protection criteria. Therefore, the Orange County 100-year design storm and associated performance criteria were adopted for this study. The ultimate hydrological objective is to ensure that the existing discharge rate into the Stanton Storm Channel during a 100-year storm is not exceeded under the proposed site conditions.

The SERC site is located within Zone X as defined by the Federal Emergency Management Agency (FEMA). Zone X generally indicates a 0.2 percent chance of flooding in any given year – also known as the 500-year floodplain. Zone X also indicates some potential for very shallow flooding (less than 1 foot deep) during 100-year flood conditions (FEMA, 2009). An investigation conducted by WSP|PB determined the 100-year flood level to be 71.33 feet (Appendix K). Based on discussions with the City of Stanton, the following baseline top of concrete (TOC) elevations for the equipment foundations on each parcel (see Locus Map in Appendix A) have been determined for the SERC site:

- Parcel 1 = 72.7 feet
- Parcel 2 = 71.0 feet

The SERC site falls within the jurisdictional boundaries of the Santa Ana Regional Water Quality Control Board (RWQCB). Water quality objectives for the Santa Ana River are contained in the Water Quality Control Plan for the Santa Ana River Basin (Santa Ana RWQCB, 2008) and will be incorporated in the next phase of the drainage design. This study addresses the peak stormwater discharge rate criteria based on a 100-year, 24-hour design storm.

Based on the hydrologic and hydraulic modelling and assessment undertaken, the proposed site conditions were deemed to satisfy the 100-year stormwater discharge rate criteria set out in the Orange County Hydrology Manual. This is illustrated in Table 1 which shows the maximum total discharge rates from the site for the existing and proposed conditions.

Table 1 – Comparison of	Maximum T	Total Discharge	Rates for Existing	and Proposed Conditions

Discharge Location	Existing Condition Discharge Rate (cfs)	Proposed Condition Discharge Rate (cfs)
Via 36-inch outfall	8.6	9.6
Via 24-inch outfall	4.3	1.5
To Dale Avenue street drainage	0.3	0.3
TOTAL Site Discharge (hydrographic)	10.8	10.5

As the whole-of-site site maximum total discharge rate for the proposed condition was found to be less than that for the existing condition, the proposed drainage system was deemed to satisfy the OCHM requirements. Therefore the construction of the SERC Project and proposed drainage system are not



expected to adversely affect or substantially alter the existing watershed, the Stanton Storm Channel, or the tributaries crossing the project site.

Section 2 Project Overview

2.1 Project and Site Description

The SERC site is within the Coastal Plain of Orange County Groundwater Basin, which lies along the coast and has a surface area of 350 square miles. There are no natural surface water features within one mile of the site. The site itself drains to the Stanton Storm Channel, part of the Orange County Bolsa Chica drainage system.

The project site consists of two parcels bisected by the Stanton Storm Channel and adjacent to the Union Pacific Railroad (see Figure 1). Parcel 1 (on the east side of the channel) is currently vacant, unpaved, and covers 1.76 acres. Parcel 2 (on the west side of the channel) is partially paved and 2.21 acres in size. There are also two off-site areas that are expected to contribute runoff to the project site and are therefore considered part of the SERC drainage catchment.

For the purpose of the drainage system design, it was assumed that a portion of the adjacent public street runoff also contributes stormwater to the drainage system on Parcel 2, which discharges to the Stanton Storm Channel via an existing 36-inch outfall. This additional runoff area, located at the corner of Pacific Street and Fern Avenue, covers approximately 0.43 acres (Figure 1).

The second upstream contributing area lies to the north of Parcel 1 (Figure 1). This north-eastern portion of the drainage catchment will remain undeveloped and is not considered part of the watershed associated with the SERC project. However, due to its pre-existing surface flow patterns, while part of this area will continue to drain to the channel directly, a portion of the area will also flow south towards the project site, as shown in the Preliminary Surface Flow figure in Appendix B. This runoff will be directed to an existing 24-inch outfall which discharges to the channel.

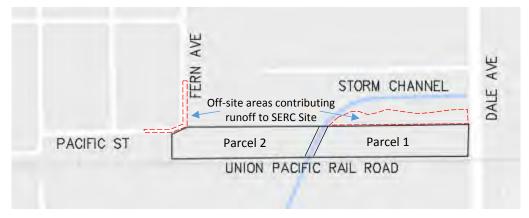


Figure 1 – Project Site and Associated Catchment Area

The proposed SERC site will contain a variety of structures and equipment including gas turbine generators, electrical enclosures, switchgear, demineralized water tank, RO skid, gas metering station, gas compressor, switchyard, ammonia tank, fin-fan coolers, CEMS building, 480 V auxiliary transformers, air



compressor skid, air fans, access roads, and other the miscellaneous structures and equipment. Refer to Appendix C for General Arrangement Drawings.

According to the "Preliminary Geotechnical Investigation" report prepared by NV5 West, Inc. (NV5), dated October 27, 2016 (refer to Appendix D for excerpt), groundwater was encountered at a depth of approximately 20 feet below the existing ground surface. Percolation testing was also performed at four location across the site, with infiltration rates ranging from 38 to 99 inches per hour.

2.2 Study Objective

The objective of this study was to evaluate the existing and proposed drainage characteristics of the site, and develop a site grading and drainage design for the SERC Project that complies with all applicable laws, ordinance, regulations and standards. The general site grading will establish a working surface for construction and plant operating areas, and will provide positive drainage from buildings and structures.

The Orange County Environmental Management Agency requires all drainage plans to demonstrate compliance with the 100-year flood protection criteria. Thus, the 100-year Orange County design storm and associated performance criteria were adopted for this study. The ultimate hydrological objective is to ensure that the existing discharge rate into the drainage channel during a 100-year storm is not exceeded under the proposed site conditions.

Section 3 Software

The AES software is designed with separate modules that are programmed to meet specific county requirements, which in turn meet all agency requirements. The Orange County preset methods and parameters were selected for use in this study.

3.1 AES 2014 RATSCx (Rational Method Analysis)

The Basic Complexity Rational Method within this module was utilized for the hydrological analysis. The peak runoff rate and time of concentration for each catchment area were determined using this module.

3.2 AES 2014 CH1 (Computational Hydraulics 1)

The Unit Hydrograph Method Loss Rate Estimation (Orange County Procedures) function within this module was used to determine the Soil Loss Rate and Low Loss Fraction for each catchment area. These results combined with the Rational Method outputs became inputs for the Small Area Unit Hydrograph Analysis carried out by this module, which was used to develop the discharge hydrographs for each catchment area. The Flow-Through Detention Basin Routing Model contained in this module was also used to develop a hydrograph reflecting the attenuation achieved by the proposed detention basin.

3.2 AutoDesk Storm and Sanitary Analysis

This software package was used to model the hydraulics of the proposed detention basin to determine the outflow from the basin at different water levels within the basin. It was necessary to use this additional modelling software as the AES package does not model the full system hydraulics when routing flow through complex drainage structures. A graphical representation of the results from this modelling and the adopted depth-flow-volume relationship can be seen in Figure 2.



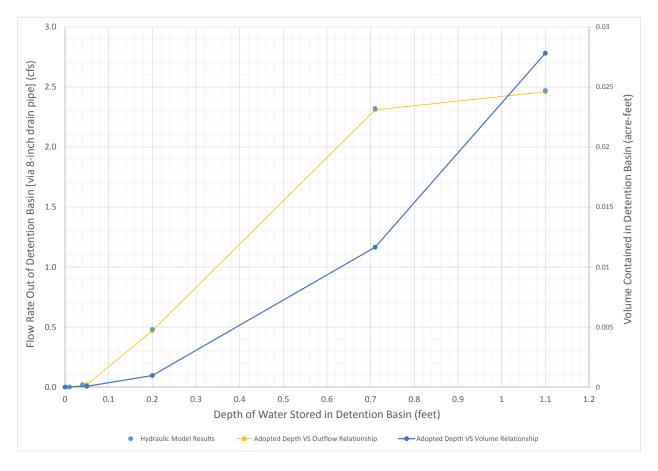


Figure 2 – Detention Basin Hydraulic Model

Section 4 Basis of Assessment

4.1 Hydrology Design Criteria

The hydrologic assessment undertaken for this project was based on the computational techniques and criteria outlined in the Orange County Hydrology Manual, October 1986 (OCHM). These were applied through the use of the aforementioned AES software, with the Rational Method adopted as the accepted methodology for watersheds that cover less than 640 acres (one square-mile).

The pre-defined parameters provided for the Orange County Method within the AES software were used in the development of the 100-year storm response. As the project area is completely below 2000 feet elevation, the non-mountainous point precipitation values were used. To simulate the high runoff potential associated with a saturated watershed (typical for 100-year storm events) the Antecedent Moisture Condition – III (AMC III) was adopted.

4.2 Hydrologic Soil Type



The preliminary geotechnical investigation conducted for the project concluded that the near-surface soils (upper 110 feet) on the site exhibit high percolation characteristics. It therefore recommended that an infiltration rate of 12 inches per hour be adopted – this includes a safety factor of three.

The OCHM categorizes the infiltration potential of soils into four groups, with Group A having the highest infiltration rates (lowest runoff potential) of greater than 0.3 inches per hour. The OCHM also includes soil maps that indicate the expected distribution of these soil categories across the county.

While the OCHM maps showed the project site to be in a Soil Group B area, the in-situ test results and consequential recommendations of the geotechnical investigation point to infiltration rates significantly higher than the minimum required for a Group A classification. Therefore, a Group A Soil Type was adopted for the hydrological analysis.

It should be noted that due to limitations within the AES software package, an infiltration rate of greater than 10 inches per hour could not be entered. Therefore, this upper bound was used in the development of the hydrological model.

4.3 Curve Numbers

The Rational Method and Hydrograph Method modules within the AES software utilize slightly different sets of curve numbers to carry out their calculations, so it was necessary to adopt two different but consistent curve number schemes for the existing and proposed site conditions. Table 2 summarizes the curve numbers (CN) adopted for each method. It should be noted that the Rational Method CN are reported after adjustment for AMCIII, whereas the Hydrograph Method CN are AMCII base inputs.

Surface Condition	Rational Method CN	Hydrograph Method CN
Impervious/Concrete/Paved Areas	98 (Commercial)	98 ⁱⁱ
Proposed Compacted Gravel Road	55% Comm. – 45% Pasture i	76 ⁱⁱ
Proposed Gravel Fill	47% Comm. – 53% Pasture i	72 ⁱⁱⁱ
Proposed Sub-Station Rock	43% Comm. – 57% Pasture i	70 ^{'''}
Proposed Open/Vegetated Space	53 (Urban Turf – Good)	39 ⁱⁱ
Existing Patchy Grassland	69 (Pasture, Dryland – Fair)	49 ⁱⁱ

Table 2 - Adopted Curve Numbers

- i. As the AES software did not provide CN for these surface materials within the Rational Method module, two available CN (*Commercial* and *Pasture, Dryland Fair*) were weighted to approximate the CN used in the Hydrograph Method.
- ii. As per the National Resources Conservation Service Technical Release 55 Table 2.2 (see Appendix E).
- iii. As there are no specific CN provided for these surface types, the proposed Gravel Fill was approximated by taking the average value of the CN for Gravel Roads and Open Space, while the proposed Sub-Station Rock was assumed to be slightly coarser than the Gravel Fill, thus a slightly lower CN was adopted.

4.4 General Assumptions

The following assumptions were also made in undertaking the drainage assessment:

- Where available survey did not indicate inlet invert elevations, a drop of 2.5 feet from the ground surface (rim elevation) of inlets was assumed.
- It was assumed that the outfalls to the channel would not be discharging against an adverse hydraulic grade line i.e. they would operate as free outfalls during the design storm.
- The general Orange County rainfall intensities were adopted and isohyetal maps were not used.



Section 5 Existing Site Conditions

5.1 Catchment Hydrology

Runoff from the west side of the channel (western subcatchment) is collected by an existing drainage system and discharges to the channel via a 36-inch pipe. Note that it was assumed that the drain on the corner of Pacific Street and Fern Avenue contributes stormwater collected from the street to the 36-inch drain. The area contributing to this inlet was assumed to extend to the midway point between the apparent drainage manhole covers in either direction from the corner, and to the centerline of the road.

Runoff originating from the east side of the channel flows across a relatively flat grassy field before doing one of the following:

- Directly flowing to the drainage channel by spilling over the edge of the channel when it reaches the north-western boundary of the lot (limited area discounted from study);
- Collecting at a small headwall in the south-western corner of the lot and draining to the channel via an existing 24-inch pipe (majority of eastern area eastern subcatchment); or
- Flowing into the street drainage system on Dale Avenue (small area own subcatchment).

While the majority of the runoff from the eastern side of the channel was accounted for, this study only considers the runoff associated with the SERC drainage catchment, and therefore the runoff that flows directly into the channel was discounted from the study.

The existing site drainage was assessed based on the hydrological system shown in Figure 3 below as well as Appendix L. The AES software outputs can be found in Appendix F.



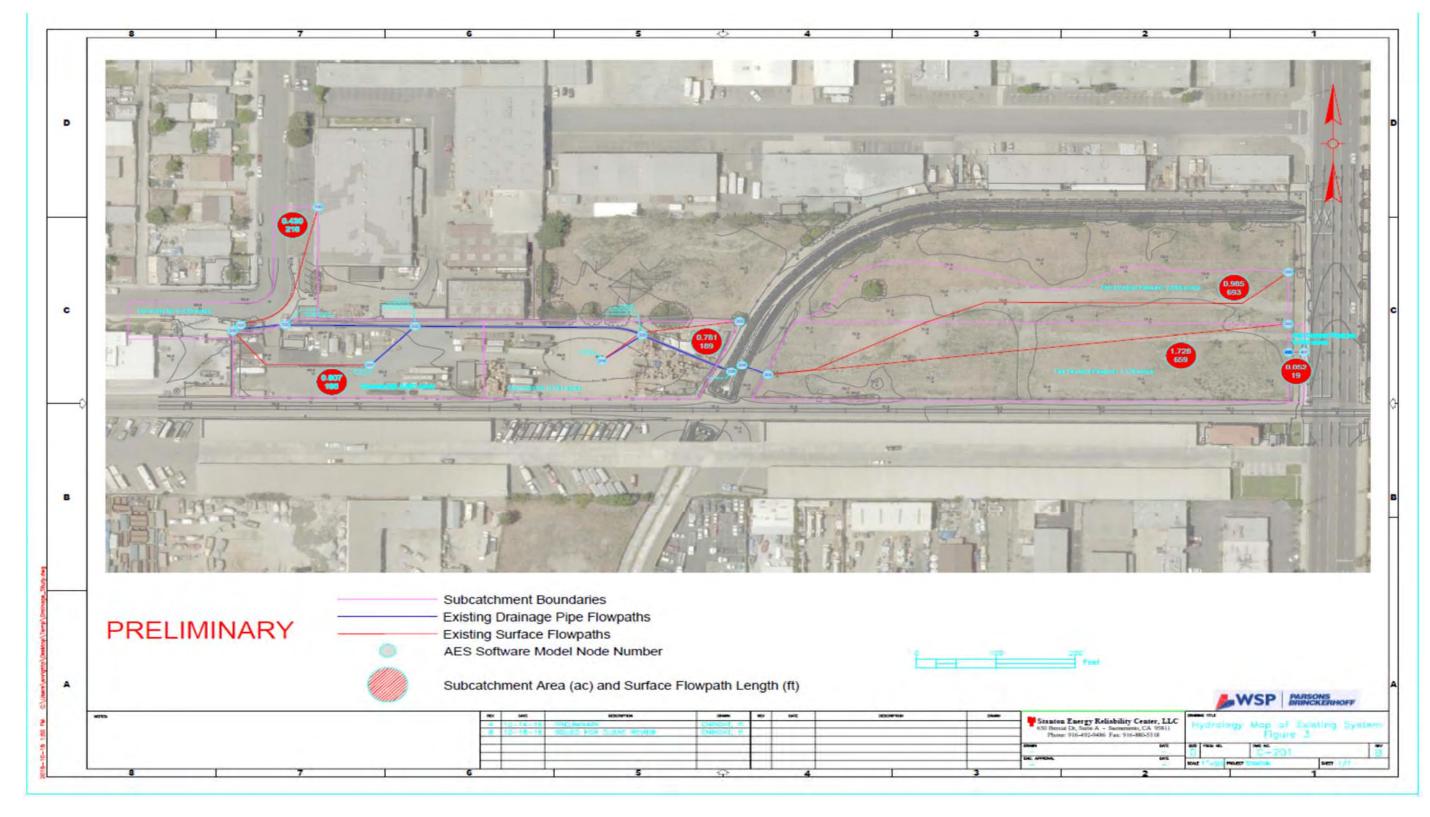


Figure 3 – Hydrology Map of Existing System



5.2 Rational Method Peak Runoff

The peak runoff rates from each of the catchment areas, as indicated by the Rational Method, are shown in Table 3.

Table 3 – Existing Condition Rational Method Peak Runoff Rates

Catchment Area Acreage Peak Runoff Rate (cfs)

Catchment Area	Acreage	Peak Runoff Rate (cfs)
Western Subcatchment	2.02	8.6
Eastern Subcatchment	2.71	4.3
Dale Avenue Subcatchment	0.05	0.3

It can be seen that the western subcatchment, due to its existing impervious surface, has a much higher runoff rate than the rest of the site, despite covering a smaller area than the eastern subcatchment.

5.3 Discharge Hydrograph

The discharge hydrograph shown in Figure 4 illustrates the difference in the timing of the runoff peaks associated with the catchment areas. The western subcatchment runoff peak occurs sharply and then subsides quickly due to the impervious nature of the ground surface and the concentrated flow paths provided by the existing drainage system. In contrast, the eastern subcatchment runoff discharges more gradually due to the vegetated ground surface and the fact that the largely flat expanse has no drainage features, which results in runoff travelling across the majority of the area as sheet flow.

The maximum total discharge rate for the existing site was determined to be 10.8 cfs. Note that this is not equal to the sum of the peak catchment runoff rates shown in Table 3 due to the fact that the peak catchment runoff rates do not (in this case) occur simultaneously. It should also be noted that this total includes a component of runoff that discharges to Dale Avenue, rather than to the drainage channel. The maximum total discharge rate to the channel only was calculated to be 10.6 cfs.

The maximum total discharge rate (i.e. the maximum rate at which stormwater flows off of the site) for the existing condition (10.8 cfs in this case) is the key criteria to which the project drainage design must conform. This pre-development condition must be, at a minimum, maintained in the post-development condition, in order to satisfy the OCHM requirements.



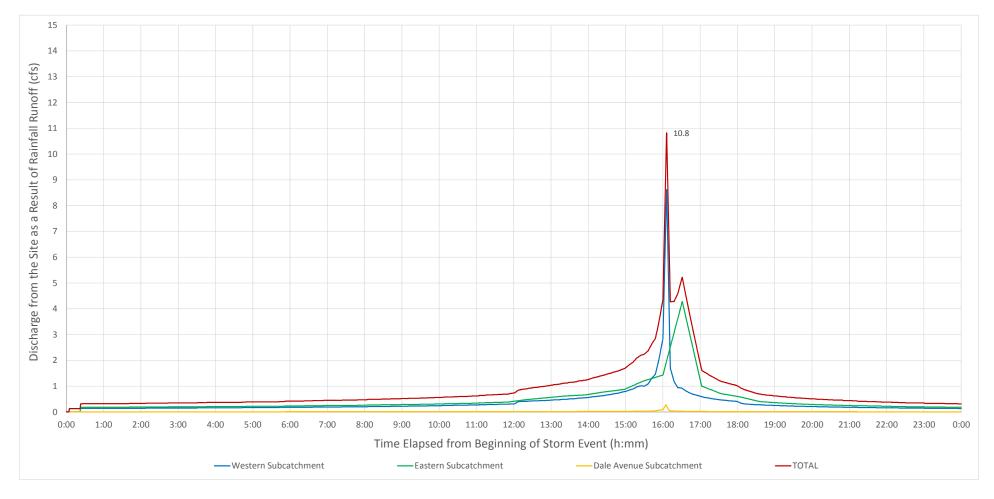


Figure 4 – Discharge Hydrograph for Existing System



Section 6 Proposed Site Conditions

6.1 Proposed Infrastructure

All on-site runoff will be collected by the proposed drainage system and potentially contaminated water will be detained prior to discharging into the Stanton Drainage Canal, in accordance with regional hydrology standards. The following describes the proposed conditions on Parcel 1 and Parcel 2. Appendix G contains the Preliminary Grading and Drainage design drawings.

- Parcel 1 will contain an underground stormwater collection system (inlet, pipe and structure) linking the paved roadway areas, the equipment foundation pad area and the transformer area. This collection area will be directed to a new lift station located adjacent to the Stanton Storm Channel. The lift station will contain submersible pumps that will transfer the stormwater to the aboveground stormwater detention tank on Parcel 2 through a force main which crosses the channel via a utility bridge.
- The area north of Parcel 1 is outside of the SERC project limits, but a portion of it currently drains through Parcel 1 towards an existing headwall and 24-inch diameter outfall pipe, which discharges directly to the Stanton Storm Channel. To retain this drainage pattern, runoff from the area north of Parcel 1 will be directed to a pipe culvert under the proposed vehicle bridge, which will cross the Stanton Storm Channel. This pipe will connect directly to the existing outfall pipe and will not be day-lighted on Parcel 1. This will allow the off-site runoff to be directly routed to the Stanton Storm Channel without mingling with runoff from Parcel 1.
- Parcel 2 will retain the existing underground stormwater collection system and the east half of the parcel will be graded to a new stormwater detention basin, which will discharge to the existing underground drainage system. All runoff from Parcel 2 will enter the existing 36-inch pipe and discharge to the Stanton Storm Channel.
- Parcel 2 will also house an above-ground stormwater detention tank, where the stormwater from Parcel 1 will be detained and then released in a controlled manner to the adjacent proposed detention basin for water quality compliance. As noted above, the detention basin will drain to the existing inlet, through the existing 8-inch pipe, then 36-inch pipe, before discharging to the Stanton Storm Channel.
- Portions of Pacific Street and Fern Avenue are assumed to be connected to a 24-inch pipe connected to the upstream end of the existing 36-inch drain pipe located on Parcel 2. As mentioned previously, it was assumed that a portion of the street drains to the existing 36-inch pipe.

6.2 Detention Basin Design

The detention basin proposed for Parcel 2 will drain to an existing drain inlet which has a rim elevation of 68.3 feet. It was assumed that at least half a foot of clearance would be desired between the 69.9 foot minimum elevation of the proposed road which will surround the basin, thus the top water level of the basin was taken to be 69.4 feet. It was also assumed that the cross-sectional area of the basin would vary linearly between the size of the drainage inlet (12.5 ft²) when the basin is empty, and the footprint of the basin (2190 ft²) when the basin is full, giving it a total volume of 1,211 ft³. Based on these assumptions the basin hydraulics were modelled and it was determined that the maximum flow rate that could be achieved through the basin and receiving 8-inch drainage pipe would be 2.46 cfs.



6.3 Catchment Hydrology

The major hydrological changes to the catchment as a result of the proposed development include:

- A modest increase in the perviousness of Parcel 2 within the western subcatchment due to impervious surfaces being replaced by more pervious materials;
- The addition of a detention basin on Parcel 2 in the western subcatchment which will attenuate runoff rates by providing temporary storage and increasing routing times;
- The development of Parcel 1 replacing the southern half of the predominantly pervious eastern subcatchment with significantly less pervious surface materials;
- The provision of a constructed drainage inlet and pipe system to collect runoff from Parcel 1 within the eastern subcatchment; and
- A pump station and tank storage system which will initially attenuate and then direct all on-site runoff from Parcel 1 to the Parcel 2 drainage system, before eventually discharging to the channel.

At sites like the proposed SERC, it is typical practice to collect the runoff from areas surrounding certain equipment installations, pass it through oil-water separators and other filtration systems, and then dispose of it independently of the stormwater drainage system. However, at the current stage of planning, the specific layout of these systems has not been defined and these discounted areas cannot be quantified. Therefore, although ultimately there will be areas of impervious runoff that never contribute to the runoff collected by the drainage system, a conservative approach was adopted and no such areas were discounted from the assessment.

The proposed site drainage was assessed based on the hydrological system shown in Figure 5 below as well as Appendix L. It should be noted that the diameters of the proposed drainage pipes were not specified prior to running the Rational Method module of the AES software. These pipes were sized by the software based on the predicted inflows and required flow capacities calculated during the model simulations. The AES software outputs can be found in Appendix H.



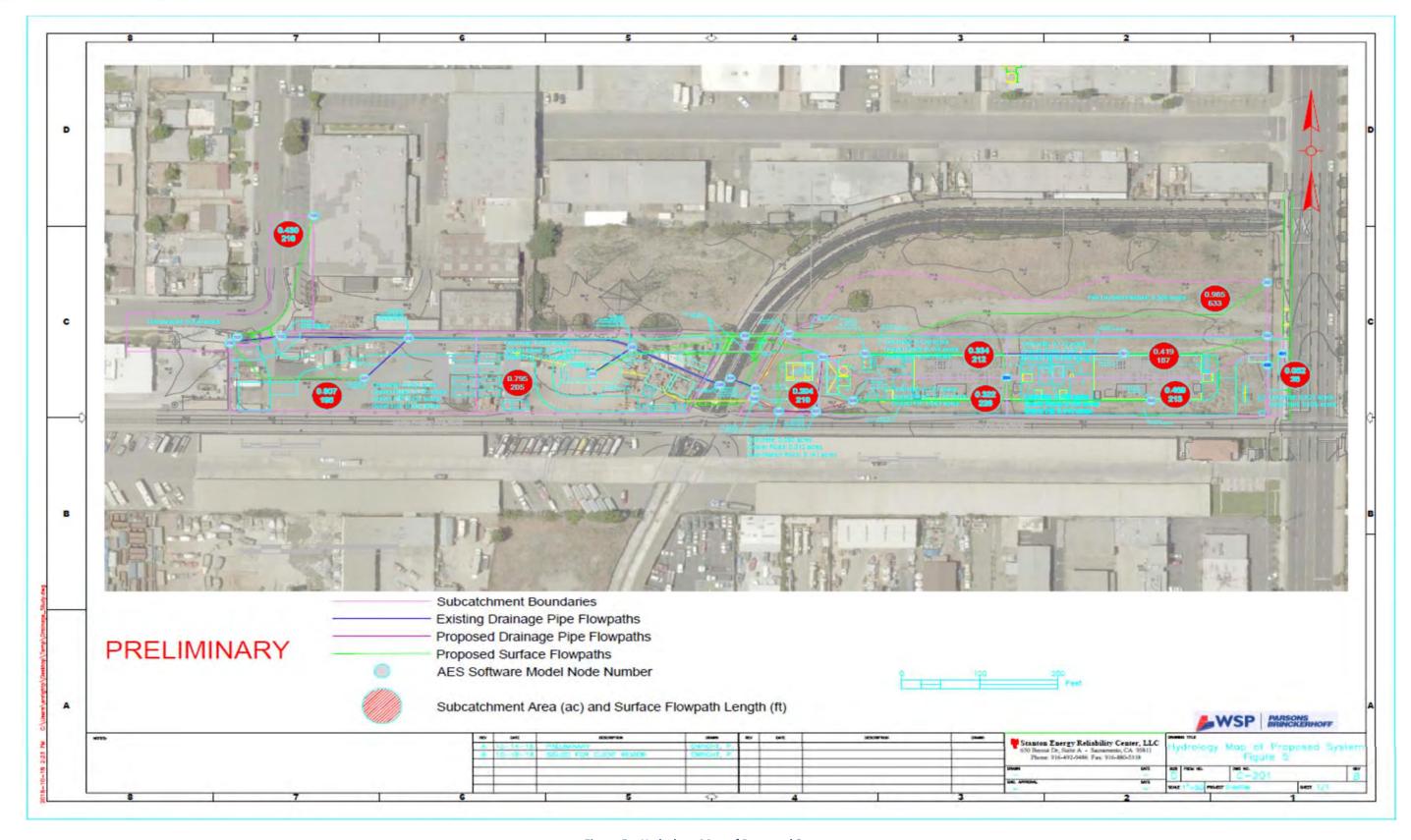


Figure 5 – Hydrology Map of Proposed System



6.4 Rational Method Peak Runoff

The peak runoff rates from each of the catchment areas, as indicated by the Rational Method, are shown in Table 4.

Catchment Area	Acreage	Peak Runoff Rate (cfs)
Western Subcatchment (Direct to Channel)	1.24	5.1
Western Subcatchment (Through Detention Basin)	0.80	2.4
North Eastern Subcatchment (Off-Site)	0.99	1.5
South Eastern Subcatchment (On-Site, Pumped)	1.75	6.6
Dale Avenue Subcatchment	0.05	0.3

Table 4 - Proposed Condition Rational Method Peak Runoff Rates

It can be seen that although the total catchment area associated with the western subcatchment was increased by the addition of the bridge deck, the combined peak runoff rate for the western subcatchment (7.5 cfs) is less than the existing peak runoff rate (8.6 cfs) due to the reduction of the impervious ground surface. Conversely, the increase in impervious surface associated with the development of Parcel 1 within the south east subcatchment can be seen to have dramatically increased the peak runoff rate.

6.5 Discharge Hydrographs and System Operation

The potential discharge hydrograph shown in Figure 6 illustrates the potential peak discharge rate from the site if no attenuation of the runoff from southeast subcatchment is achieved – i.e. the inflows to the pump station instead discharged directly to the channel. However, the drainage system has been designed such that the runoff generated by the development of Parcel 1 is pumped to the proposed storage tank on Parcel 2. The stored water can then be discharged at a controlled flow rate so as not to exceed to the pre-development maximum total discharge rate for the site.

The proposed operation of the system, from a hydrographic perspective, is shown in Figure 7. While the pumped runoff (light green) can be subtracted from the potential total discharge hydrograph to give the direct discharge hydrograph (dark red), the volume that would be accumulated in the storage tank (purple) over the full duration of the design storm exceeds the capacity of the storage tank. Therefore, it is necessary to release some of the stormwater stored in the tank over the course of the storm.

As the tank may ultimately be required to release its contents to the adjacent detention basin to meet water quality criteria, the discharge rate from the tank cannot exceed the maximum flow-through rate of the detention basin – 2.4 cfs. The green dashed line in Figure 7 shows the resulting total discharge if the tank is allowed to drain at a rate of 2.4 cfs once it reaches 90% of its capacity - this provides at least 2 feet of freeboard to the top of the tank - while the dashed blue line tracks the corresponding stored volume in the tank.

The maximum total discharge rate for the proposed site under these operational parameters was thus determined to be 10.5 cfs – less than the pre-development maximum total discharge rate of 10.8 cfs. Note that the maximum total discharge rate to the channel only was calculated to be 10.4 cfs for the proposed system and operational parameters. The pre-development runoff conditions are thus expected to be improved post-development, and therefore the OCHM requirements can be satisfied.



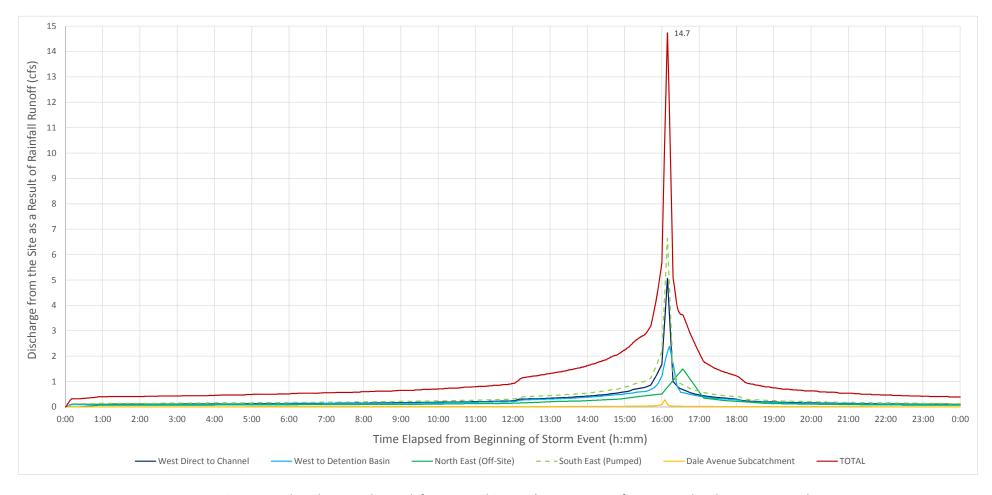


Figure 6 – Potential Discharge Hydrograph for Proposed System (not accounting for pump and tank storage system)



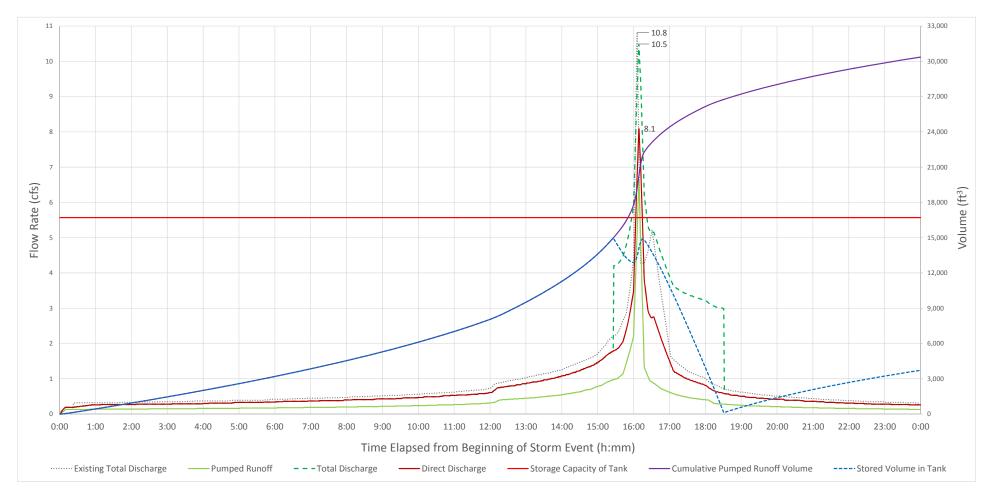


Figure 7 – Attenuated Discharge Hydrograph for Proposed System (accounting for pump and tank storage system)



6.6 Pump Station Configuration

Based on the peak runoff rate from the south east subcatchment, the pump station will need to achieve a total duty of 6.6 cfs in order to pass forward the maximum inflow to the station. The pump station should be designed to reliably achieve the total duty required for a 100-year storm event.

Based on the American National Standard for Pump Intake Design (see Appendix I for criteria) and a generic pump station configuration, it is estimated that a 300 ft3 (2230 USG) wet well will be required for the pump station. The well shall have a 6.4 foot diameter and be 9.2 feet deep, relative to a top elevation of 70.5 feet. The operating volume within this well will be approximately 160 ft3 based on a 5 foot controlled operating level range.

Section 7 Summary

The existing and proposed SERC site conditions were modelled to determine the storm response and runoff generated by each system. The proposed drainage system configuration and operational parameters were also determined to satisfy the OCHM requirements. Based on the hydrologic and hydraulic modelling and assessment undertaken, the proposed site conditions were deemed to satisfy the OCHM requirements for stormwater discharge rates for a 100-year storm event.

Table 5 shows the peak runoff rates predicted by the Rational Method for the existing and proposed site conditions. It should be noted that the peak runoff rates do not occur simultaneously, and in the case of the proposed condition, the attenuation achieved through the pump station and holding tank system is not reflected in these results.

Table 5 – 0	Comparison of	f Rational N	Method Pea	k Runofi	f Rates f	for Existing and	l Proposed Conditio	ns

	Peak Runoff Rates (cfs)		Proposed Area
Catchment Area	Existing	Proposed	Total (cfs)
West Subcatchment (Direct to Channel)	9.6	5.1	7.5
West Subcatchment (Detention Basin)	8.6	2.4	
North East Subcatchment (Off-Site)	4.2	1.5	8.1
South East Subcatchment (Pumped)	4.3	6.6	8.1
Dale Avenue Subcatchment	0.3	0.3	0.3

Table 6 shows the maximum total discharge rates from the site for the existing and proposed conditions. These results do account for the attenuation provided by the pump station and holding tank system, and form the basis of the pre-development and post-development comparison required to assess whether or not the OCHM standards are met.



Table 6 – Comparison of Maximum Total Discharge Rates for Existing and Proposed Conditions

Discharge Location	Existing Condition Discharge Rate (cfs)	Proposed Condition Discharge Rate (cfs)
Western Subcatchment via 36-inch outfall	8.6	9.6
Eastern Subcatchment via 24-inch outfall	4.3	1.5
From Dale Avenue Subcatchment to street	0.3	0.3
TOTAL Site Discharge (hydrographic)	10.8	10.5

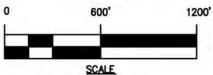
It can be seen that due to the transfer of the on-site runoff from Parcel 1 to the holding tank on Parcel 2, the peak discharge via the 36-inch outfall is increased, while the peak discharge from the 24-inch outfall is decreased. As the whole-of-site site maximum total discharge rate for the proposed condition was found to be less than that for the existing condition, the proposed drainage system was deemed to satisfy the OCHM requirements.



APPENDIX A

LOCUS MAP







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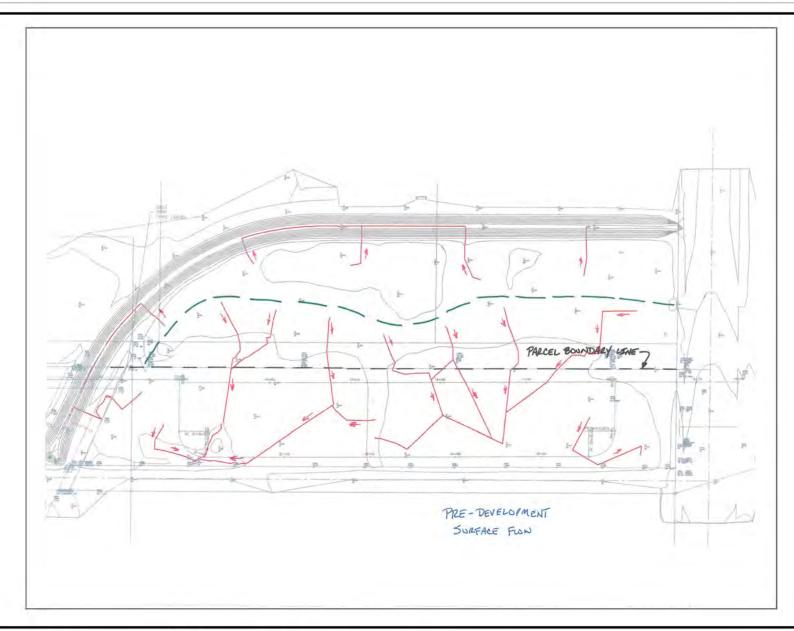
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APPENDIX B



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Sub-Consultant:

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Project:

Scale: N/A

Date: 10/14/16

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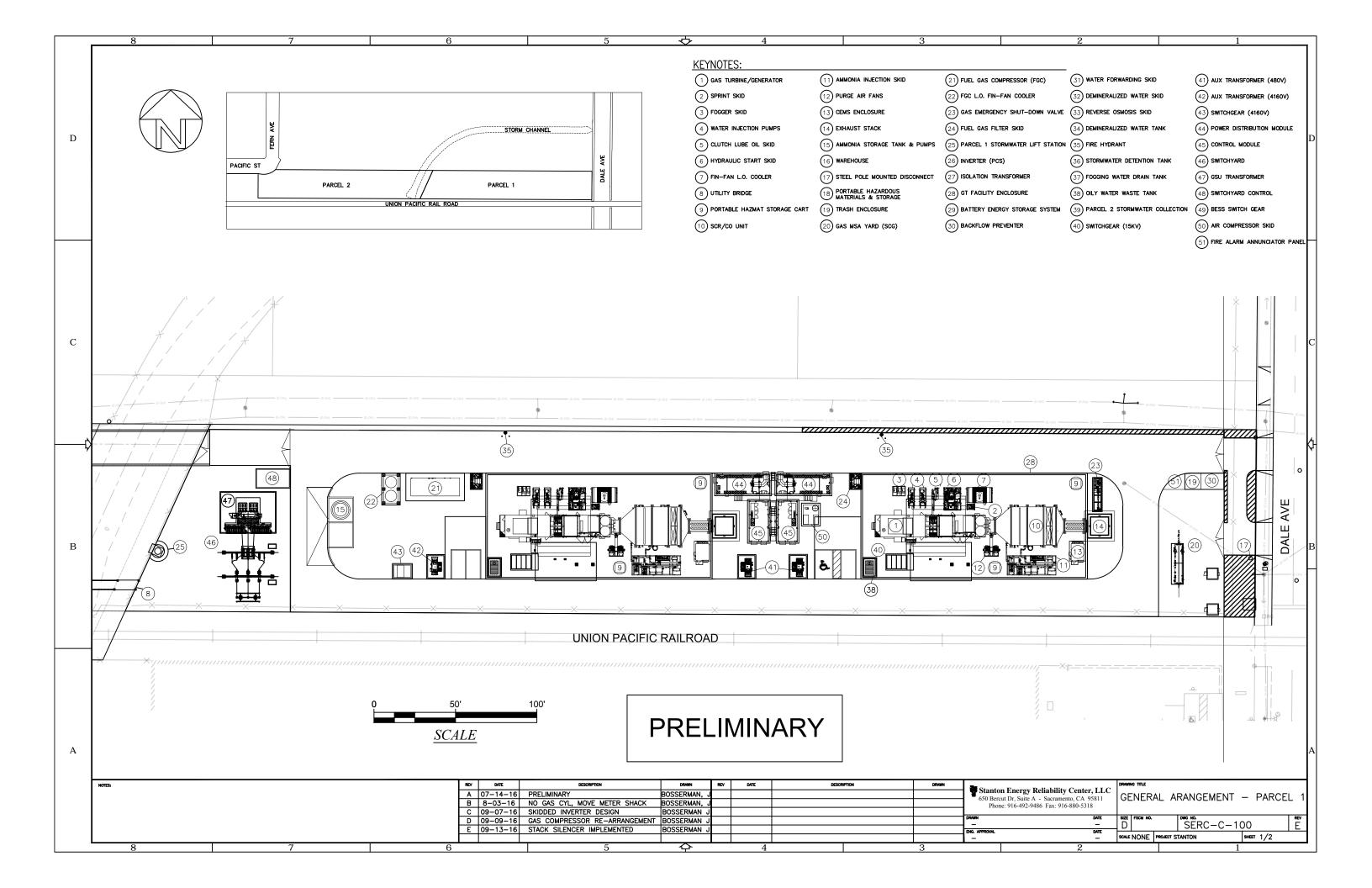
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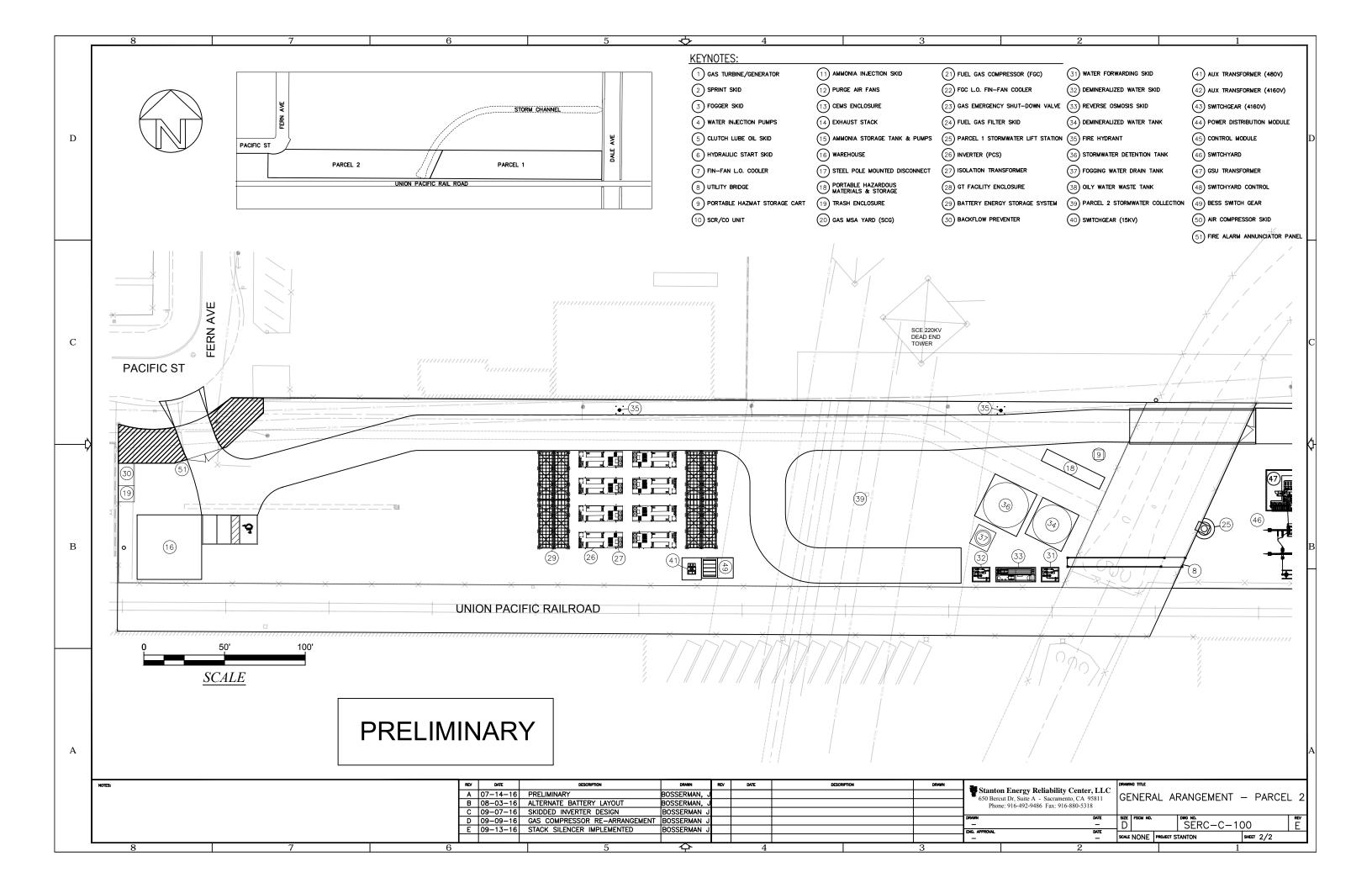
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APPENDIX C







APPENDIX D

PRELIMINARY GEOTECHNICAL INVESTIGATION STANTON ENERGY RELIABILITY CENTER STANTON, CALIFORNIA









October 27, 2016

NV5

NV5 West, Inc.

10592 Avenue of Science, Suite 200 San Diego, California 92128 (858) 715-5800 www.NV5.com



Stanton Energy Reliability Center, LLC 650 Bercut Drive, Suite A Sacramento, California 95811

Attention: Mr. Paul Cummins

Subject: Preliminary Geotechnical Investigation

Project: Proposed Stanton Energy Reliability Center

> West of Dale Street Stanton, California

Dear Mr. Cummins:

As requested, NV5 West, Inc. (NV5) is pleased to submit the results of our preliminary geotechnical investigation for the subject project. The purpose of this investigation was to evaluate the subsurface conditions at the proposed Stanton Energy Reliability Center site located on the west side of Dale Street in Stanton, California. The results of the geotechnical field exploration, laboratory tests, and preliminary geotechnical engineering recommendations and conclusions are presented herewith.

Based on the subsurface exploration, subsequent testing of the subsurface soils, and engineering analyses it was concluded that the construction of the proposed project is geotechnically feasible. The geotechnical information presented herein is intended to assist the project design team in their understanding of the geotechnical factors affecting the proposed project, and the preliminary recommendations, should be incorporated into the project design and implemented construction.

It is recommended that the forthcoming project specifications, in particular the earthwork/compaction sections, be reviewed by NV5 for consistency with our report prior to the bid process in order to avoid possible conflicts, misinterpretations, and inadvertent omissions, etc. It should also be noted that the applicability and final evaluation of recommendations presented herein are contingent upon construction phase field monitoring by NV5 in light of the widely acknowledged importance of geotechnical consultant continuity through the various design, planning and construction stages of a project.

OFFICES NATIONWIDE

October 27, 2016

Project No.: 113815-00763.00

NV5 appreciates the opportunity to provide this geotechnical engineering service for this project and looks forward to continuing our role as your geotechnical engineering consultant.

Respectfully submitted,

NV5 West, Inc.

Gene Custenborder, CEG 1319

Senior Engineering Geologist

ENGINEERING
GEOLOGIST
OF 11130-16

Sam Koohi, PhD., PE 85010

Engineering Manager

5010 No. C 85010 Exp. 03/31/18

Reviewed by:

Guillaume Gau, GE 2986

Senior Vice President



GC/SK/GG:ma

Distribution: (3) Addressee, (1) via email Stanton Energy Reliability Center Geotechnical Report.doc



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1.0 INTRODUCTION

This report presents the results of NV5's preliminary geotechnical investigation for the proposed Stanton Energy Reliability Center site (SERC) in Stanton, California. The approximate location of the project area is shown on *Figure 1*, *Site Location Map*. The purpose of this study was to evaluate the subsurface conditions and to provide preliminary geotechnical recommendations for the design and construction of the proposed development. From information presented on a preliminary site plans and our discussions with you, it is understood that the proposed development will include gas turbine generators, gas compressors, gas metering station, switchyard, and associated equipment. This report summarizes the data collected and presents our findings, conclusions, and preliminary recommendations.

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This report has been prepared for the exclusive use of the client and their consultants to describe the geotechnical factors at the project site which should be considered in the design and construction of the proposed project. In particular, it should be noted that this report has not been prepared from the perspective of a construction bid preparation instrument and should be considered by prospective bidders only as a source of general information subject to interpretation and refinement by their own expertise and experience, particularly with regard to construction feasibility. Contract requirements as set forth by the project plans and specifications will supersede any general observations and specific recommendations presented in this report.

2.0 SCOPE OF SERVICES

The scope of services for this project consisted of the following tasks:

- Review of a preliminary site plan.
- Review of readily available background data, including Client provided geotechnical data, geotechnical literature, geologic maps, topographic maps, seismic hazard maps, and literature relevant to the subject site.
- A site reconnaissance to observe the general surficial site conditions and to select boring locations.
- Preparation of an Orange County Health Care Agency, Environmental Health Division, geotechnical boring construction permit.
- A subsurface investigation, including the excavating, logging, and sampling of six exploratory borings located within the project area to depths of approximately 51.5 feet below the existing ground surface. Soil samples obtained from the borings were transported to NV5's in-house laboratory for observation and testing.
- Field percolation testing to evaluate the infiltration characteristics of the onsite soils.
- Laboratory testing of selected soil samples to evaluate their pertinent geotechnical engineering properties.
- An assessment of faulting, seismicity, liquefaction, and other geologic hazards affecting the area and possible impacts on the subject project.



• Engineering evaluation of the geotechnical data collected to develop geotechnical recommendations for the design and construction of the proposed project.

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 Preparation of this report, including reference maps and graphics, summarizing the data collected and presenting our findings, conclusions, and geotechnical recommendations for the design and construction of the proposed project.

3.0 SITE AND PROJECT DESCRIPTION

The proposed SERC site is located in the southern portion of the vacant parcel located west of Dale Avenue, south of Standustrial Street and north of a railroad right-of way in Stanton, California. The property is relatively level at an elevation of approximately 68 feet above mean sea level. A southerly flowing, concrete-lined drainage channel crosses the western portion of the site. (refer to *Figure 2*, *Geotechnical Map*). The property is currently undeveloped, has a perimeter chain-link fence, and is sparsely vegetated weeds. Overhead electrical transmission lines are located immediately to the north and east sides of the site, and two electrical transmission line towers exist immediately to the northwest of the site.

Based on preliminary information it is understood that the proposed construction includes a gas turbine generator, electrical enclosure, switchgear, demineralized water tank, RO skid, gas metering station, gas compressor, switchyard, ammonia tank, fin-fan cooler, CEMS building, 480 V auxiliary transformer, air compressor skid and tempering air fan access road, and other miscellaneous structures and equipment.

4.0 FIELD EXPLORATION

Before starting the field exploration program, a field reconnaissance was conducted to observe site conditions and check locations for the planned subsurface explorations. NV5 obtained a DEH geotechnical boring construction permit (LMWP-002408). As required by law, Underground Service Alert was notified of the locations of the exploratory borings prior to drilling.

The subsurface conditions were explored by drilling, logging, and sampling six exploratory borings located within the project area to a maximum depth of approximately 51.5 feet below ground surface (bgs). The borings were drilled using a truck-mounted hollow-stem auger drill rig. The drilling services were provided by J.&H. Drilling Company of Buena Park, California. The approximate locations of the exploratory borings are presented on *Figure 2, Geotechnical Map*, and on the project General Arrangement drawings. Details of the subsurface exploration and logs of the exploratory borings are presented in *Appendix A*. Subsequent to logging and sampling, the borings were backfilled in accordance with the permit requirements.

5.0 PERCOLATION TESTING

Field percolation testing was performed to evaluate the infiltration characteristics of the onsite soils to obtain information regarding the feasibility of storm water runoff infiltration. Percolation tests were performed in four borings. Two of the tests were in borings that were drilled to approximately 5 feet bgs and two were in borings that were drilled approximately 10 feet bgs. The borings were 4 inches in diameter and a 2-inch diameter PVC casing was installed in the borehole prior to testing. The approximate locations of the percolation tests are presented on *Figure 2*.



Prior to conducting the percolation tests, each test hole was filled with clear water and allowed to presoak overnight to simulate actual operating conditions. The following day, the boring was refilled with water. Water level measurements were taken from the top of the test hole to the water level in the pipes at various time increments. Due to the relatively high percolation rates, a minimum of four cycles of filling and measuring the water levels were performed in each of the borings. The results of the percolation tests are presented in the following Table 1.

Table 1
Percolation Test Results

Test Number	Depth Below Ground)	Soil Description	Infiltration Rate (minutes per inch)	Infiltration Rate (inches per hour)
P-1	5.3 feet	Light brown silty sand (SM)	0.80	75
P-2	10.1 feet	Gray-brown silty sand (SM)	1.06	57
P-3	5.3 feet	Brown silty sand (SM)	1.57	38
P-4	10.1 feet	Gray-brown silty sand (SM)	0.60	99

As indicated in the above table, the percolation rate was variable across the site, but in general the near-surface soils (upper 10 feet) exhibit high percolation characteristics.

The in-situ infiltration characteristics of the subsurface materials are primarily a function of the amount of fines (i.e., silt and clay size), the relative density, and other anomalies associated with the placement or natural depositional/weathering processes (e.g., compaction/lamination, smearing, cementation). As a result of the heterogeneous nature inherent with the site subsurface materials, the in-situ infiltration characteristics are variable. If the on-site soils will be used to infiltrate storm water runoff, then it is recommended that an infiltration rate of 12 inches per hour should be used in the design. The recommended infiltration rate includes a safety factor of 3.

6.0 LABORATORY TESTING

Laboratory testing was performed on selected representative bulk and relatively undisturbed soil samples obtained from the exploratory borings to aid in the soil classification and to evaluate the engineering properties of the soil materials encountered. The following tests were performed:

- In-situ moisture content (ASTM D2216)
- Sieve analyses (ASTM D422)
- Atterberg Limits (ASTM D4318)
- Expansion Index (ASTM D4829)
- R-Value (ASTM D2844)
- Corrosivity series including sulfate content, chloride content, pH-value, and resistivity (California Test Methods 417, 422, and 532/643)
- Direct shear (ASTM D3080)



Testing was performed in general accordance with applicable ASTM standards or California Test Methods. The laboratory test results and details of the laboratory-testing program are presented in *Appendix B*.

7.0 GEOLOGY

Geologic Setting - The site area is located in the south-central part of the Los Angeles physiographic basin between the Transverse Ranges physiographic Basin on the north and the Peninsular Ranges province on the south. The Los Angeles Basin is a relatively flat, low-lying coastal plain surrounded by mountains on the north east and south. The western margin of the basin is open to the sea except at the Palos Verdes hills. Major rivers and drainages throughout the basin have been modified by agricultural, urban and commercial development and are now largely confined within lined channels. Regional geological maps of Orange County (Morton and Miller, 1981; California Geological Survey, 1997) indicate the surface of the site is occupied by Holocene-age alluvium. Regional geological studies indicate that Holocene-age flood-plain sediments extend up to a depth of about 75 feet. These are primarily silts, sands, and gravels deposited by the rivers meandering across the floor of the Los Angeles Basin when they flowed under their natural regime. These units are underlain by non-indurated to poorly indurated, marine and non-marine, Pleistocene-age sediments of the Lakewood and San Pedro formations. These Pleistocene units extend to depths on the order of several hundred feet (~500 to 1,000 feet). The depth to the top of Tertiary-age sedimentary rock is more than 1000 feet deep, and crystalline basement rock is about 24,000 feet deep in the site region.

<u>Geologic Materials</u> - Geologic materials encountered during the subsurface explorations include Quaternary-aged alluvial deposits. Minor surficial deposits of fill and topsoil may also present locally. *Figure 3, General Geologic Map* presents the general distribution of geologic units in the site area. Detailed descriptions of the earth materials encountered are presented on the boring logs in *Appendix A*. A description of the geologic materials encountered are provided below:

 <u>Alluvium</u> – Quaternary-aged alluvium was encountered in all of the exploratory borings. Alluvium was encountered to the total depth explored (maximum of approximately 51.5 feet). As encountered these materials generally consisted of light brown to dark gray, moist, medium dense, micaceous, silty to clayey sands and soft to firm sandy to clayey silts.

<u>Groundwater</u> - Groundwater was encountered in all six of the exploratory borings at a depth of approximately 20 feet bgs. Groundwater levels may vary due to seasonal fluctuations and factors such as a substantial increase in surface water infiltration from landscape irrigation, agricultural activity, storage facility leaks or unusually heavy precipitation.

8.0 FAULTING, SEISMICITY AND OTHER GEOLOGIC HAZARDS

The principal seismic considerations for most facilities in Southern California are damage caused by surface rupturing of fault traces, ground shaking, seismically-induced ground settlement and liquefaction. Potential impacts to the project due to faulting, seismicity and other geologic hazards are discussed in the following sections.

Faulting - The numerous faults in southern California include active, potentially active, and inactive faults. As used in this report, the definitions of fault terms are based on those developed for the Alquist-Priolo Special Studies Zones Act (AP) of 1972 and published by the California Division of Mines and



Quaternary time.

Geology (Hart and Bryant, 2007). Active faults are defined as those that have experienced surface displacement within Holocene time (approximately the last 11,000 years) and/or have been included within any of the state-designated Earthquake Fault Zones (previously known as Alquist-Priolo Special Studies Zones). Faults are considered potentially active if they exhibit evidence of surface displacement since the beginning of Quaternary time (approximately two million years ago) but not since the beginning of Holocene time. Inactive faults are those that have not had surface movement since the beginning of

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Review of geologic maps and literature pertaining to the general site area indicates that the site is not located within a state-designated Earthquake Fault Zone. In addition, there are no known major or active faults mapped on the project site. Evidence for active faulting at the site was not observed during the subsurface investigation. The relative location of the site to known active faults in the region is depicted on *Figure 4*, *Regional Fault Map*. The distance from the site to the projection of traces of surface rupture along major active earthquake fault zones, that could affect the site are listed in the following Table 2.

Table 2
Distance from the Site to Major Active Faults

Fault	Distance From Site
Puente Hills (Coyote Hills)	4.7 miles
Newport-Inglewood	7.2 miles
San Joaquin Hills	8.2 miles
Elsinore fault (Whittier section)	10.5 miles
Palos Verdes	16.0 miles
San Jose fault	17.1 miles
Elysian Park	19.2 miles
Chino fault	19.3 miles
Sierra Madre fault	23.8 miles
San Gabriel	39.0 miles
Coronado Bank fault	36.5 miles
San Jacinto fault	41.2 miles
Northridge fault	41.3 miles
San Andreas fault	42.6 miles

<u>Seismic Shaking</u> - The project site is located in southern California which is considered a seismically active area, and as such, the seismic hazard most likely to impact the site is ground shaking resulting from an earthquake along one of the known active faults in the region. The seismic design of the project may be performed using seismic design recommendations in accordance with the 2013 California Building Code (CBC). Recommended seismic design parameters are presented in *Section 10.4* of this report.

<u>Fault Rupture</u> - The project site is not located within an Earthquake Fault Zone delineated by the State of California for the hazard of fault surface rupture. The surface traces of known active or potentially active faults are not known to pass directly through, or to project toward the site. Therefore, the potential for damage due to surface rupture of faults at the project site is considered low.

<u>Liquefaction and Seismically-Induced Settlement</u> – Liquefaction and dynamic settlement of soils can be caused by ground shaking during earthquakes. Research and historical data indicate that loose, relatively clean granular soils are susceptible to liquefaction and dynamic settlement, whereas the stability of the majority of clayey silts, silty clays and clays is not adversely affected by ground shaking. Liquefaction is generally known to occur in saturated loose cohesionless soils at depths shallower than



approximately 50 feet. The potential for liquefaction under the same conditions of ground shaking intensity and duration will decrease for sands that are more well graded, more irregular and gritty, coarser and denser. Also, a pronounced decrease in liquefaction potential will occur with the increase in fine-grained (i.e., silt and clay) content. Seed and others have suggested that a non-liquefiable classification be assigned if the clay faction is 15 percent or greater (Guidelines for Evaluating and Mitigating Seismic Hazards in California, Special Publication 117, CDMG, Ch. 6, 1997). Dynamic settlement due to earthquake shaking can occur in both dry and saturated sands. The potential consequences of liquefaction to engineered structures include loss of bearing capacity, buoyancy forces on underground structures (including pipelines), increased lateral earth pressures on retaining walls, and lateral spreading.

The project site is underlain by poorly to moderately consolidated alluvial materials. The subsurface exploration program encountered poorly to moderately consolidated alluvial silt and sand with varying contents of clay, along with a relatively shallow ground water table. The State of California Seismic Hazard Zones, Anaheim Quadrangle Map (California Department of Conservation, 1998) the site is located within a zone mapped as having potential for earthquake-induced soil liquefaction (refer to Figure 5, Liquefaction Susceptibility Map).

Liquefaction analyses were performed using the Civiltech software program LiquefyPro – Version 5.8. The Seed method was used, which consists of comparing a Cyclic Stress Ratio (CSR, earthquake "load") to the Cyclic Resistance Ratio (CRR, soil "strength") of the soil. The CRR calculations were based upon input data obtained from the test borings. All of the potential liquefaction induced settlements were performed utilizing the Tokimatsu & Seed method. Detailed information regarding liquefaction analysis is presented in a published National Center for Earthquake Engineering Research (NCEER) document referenced in *Section 13.0: References*.

Liquefaction analyses were performed utilizing the field and laboratory test data. A peak ground acceleration (PGA) value of 0.5g and an earthquake moment magnitude of Mw=6.9, as estimated for the Newport-Inglewood fault were used in the analyses. The ground water level (GWL) utilized in the analyses was 15 feet below existing ground surface. *Appendix C, Liquefaction Analysis*, contains the input data file and a graphical output identifying the potentially liquefiable zones. The magnitude of liquefaction-induced settlement ranged from 4 to 6 inches. In accordance with industry standards, the accuracy of the above settlements ranges from approximately \pm 0.5-inches to \pm 1.0-inches. The analysis indicates that the liquefaction-induced settlements would occur within the loose to medium dense sand layers.

Based on our analysis, it is estimated that up to 6 inches of total seismic settlement could occur within the footprint of proposed structures for the design-event earthquake. In addition, differential settlements could be expected. In summary, the analyses indicate that there is a potential for liquefaction, seismically-induced settlement and associated ground damage for the design-event earthquake. Methods to mitigate liquefaction potential are discussed in *Section 10.2*.

<u>Landslides and Slope Instability</u> - There are no high or steep slopes on or in close proximity to the project site. Based on the investigation, there appears to be no indications of landslides or deep-seated instability at the site.

<u>Subsidence</u> - The site is not located in an area of known ground subsidence due to the withdrawal of subsurface fluids. Accordingly, the potential for subsidence occurring at the site due to the withdrawal of oil, gas, or water is considered low.



<u>Tsunamis Inundation Seiches, and Flooding</u> – The site and surrounding areas are at an approximate elevation of 60 feet above mean sea level, the site is approximately 7 miles from the Pacific Ocean.

Therefore, tsunamis (seismic sea waves) are not considered a hazard at the site.

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The site is not located near to or downslope of, any large body of water that could affect the site in the event of an earthquake-induced failure or seiche (oscillation in a body of water due to earthquake shaking). Whelan Lake and the three small relatively shallow unlined ponds adjacent to the west of the site are not considered a hazard to the site in terms of a seismically-induced seiche.

The Stanton Storm Channel, a concrete lined drainage course, crosses the western portion of the site. The potential for flooding should be addressed by the project Civil Engineer.

9.0 CONCLUSIONS

Based on the data obtained from the subsurface exploration, the associated laboratory test results, engineering analyses, and experience with similar site conditions, it is NV5's opinion that construction of the proposed project and associated improvements is feasible from a geotechnical standpoint.

- Poorly to moderately consolidated alluvial materials consisting of silts and sands that are susceptible to liquefaction were encountered underlying the proposed project site. Measurable seismically induced settlement is likely to occur at the site as a result of the design level seismic event. Ground improvement should be incorporated into the project to mitigate potential liquefaction.
- The near-surface materials are considered compressible and not capable of reliably supporting the
 proposed recycled water reservoir and associated improvements in their present condition.
 Overexcavation and recompaction of these materials are recommended for the proposed structure
 and fill loads.
- The near-surface soils were found to have "low" expansion potential.
- Considering the relatively high rate percolation characteristics of the onsite soils, it is our opinion that Low Impact Development (LID) surface runoff infiltration systems are feasible. Infiltration should not have any adverse effects on the regional groundwater table or cause soil instability. It is recommended that a vertical clearance of 10 feet be maintained between the bottom of infiltration basins and the groundwater table.

10.0 RECOMMENDATIONS

The following preliminary recommendations are provided so that the project design team is aware of the geotechnical factors that should be incorporated into the project design and implemented construction.

10.1 Earthwork

Site grading should be performed in accordance with the following recommendations and the *Typical Earthwork Guidelines* provided in *Appendix D*. In the event of conflict, the recommendations presented herein supersede those of *Appendix D*.



- Project No. 113815-00763.00
- <u>Clearing and Grubbing</u> Prior to grading, the project area should be cleared of all significant surface vegetation, demolition rubble, pond liners, trash, debris, etc. Any buried organic debris or other unsuitable contaminated material encountered during subsequent excavation and grading work should also be removed. Removed material and debris should be properly disposed of offsite. Holes resulting from removal of buried obstruction which extend below finished site grades should be filled with properly compacted soils. Any utilities within the footprint of planned structural improvements should be appropriately abandoned.
 - Excavation and Building Pad Preparation Proposed structures should be founded entirely on properly compacted fill. In order to mitigate undesirable surface settlements and improve shallow foundations lateral support, we recommend to over-excavate a minimum thickness of approximately 3 feet below the bottom of the foundations and replace with compacted granular non-expansive or very low expansive fill. The excavation should extend laterally a distance of at least 5 feet beyond the perimeter of the footprint of proposed structures.

For heavily-loaded and settlement-sensitive structures, however, we recommend to over-excavate a minimum thickness of approximately 5 feet below the bottom of the foundations and replace with compacted granular non-expansive or very low expansive fill, reinforced with three layers of geosynthetic materials (e.g., geogrids), This geogrid-reinforced provide additional benefits for long-term performance of the foundation system by minimizing damage due to the potential hydrocompression and long-term settlements.

For the above geogrid-reinforced engineered fill, we recommend that three layers of geogrid (Tensar TX140 or equivalent) be placed within the fill. The individual geogrid sheets should overlap at least 12 inches and should extend at least five feet beyond the edge of the foundation. We recommend that the geogrid layers be placed at approximately 12 inches, 36 inches and 60 inches below the bottom of foundations.

Prior to placing the engineered fill, the soils exposed in the bottom of the excavation should be moisture conditioned and uniformly recompacted to at least 95 percent of the soils maximum density (based on ASTM D1557).

- <u>Excavatability</u> Based on our subsurface exploration, it is anticipated that the on-site soils can be excavated by modern conventional heavy-duty excavating equipment in good operating conditions.
- Structural Fill Placement Areas to receive fill and/or surface improvements should be scarified to a minimum depth of 6 inches, brought to near-optimum moisture conditions, and compacted to at least 95 percent relative compaction, based on laboratory standard ASTM D1557. Fill soils should be brought to near-optimum moisture conditions and compacted in uniform lifts to at least 95 percent relative compaction (ASTM D1557). Rocks with a maximum dimension greater than 4 inches should not be placed in the upper 3 feet of pad grade. The optimum lift thickness to produce a uniformly compacted fill will depend on the size and type of construction equipment used. In general, fill should be placed in uniform lifts not exceeding 8 inches in loose thickness. Placement and compaction of fill should be observed and tested by the geotechnical consultant.
- <u>Paved Areas, Flatwork:</u> Excavate to a depth of at least 1.0 feet below the proposed or existing subgrade elevation, whichever is greater and replace with non-expansive fill (Expansion Index



not exceeding 20) compacted to at least 95 percent relative compaction, based on laboratory standard ASTM D1557. These excavations should extend a horizontal distance of at least 2.0 feet beyond the outside perimeter.

- <u>Graded Slopes</u> Graded slopes, if planned, should be constructed at a gradient of 2 to 1 (horizontal to vertical) or flatter. To reduce the potential for surface runoff over slope faces, cut slopes should be provided with brow ditches and berms should be constructed at the top of fill slopes.
- <u>Import Soils</u> If import soils are needed, proposed import should be sampled and tested for suitability by NV5 <u>prior</u> to delivery to the site. Imported fill materials should consist of clean granular soils free from vegetation, debris, or rocks larger than 3 inches in maximum dimension. The Expansion Index value should not exceed a maximum of 20 (i.e., essentially non-expansive).

10.2 Liquefaction Potential

Based on our liquefaction analysis, it is estimated that up to 6 inches of total seismic settlement could occur within the footprint of proposed structures for the design-event earthquake. In addition, potential differential settlement on the order of 2/3 of the total settlement over a horizontal span of 40 feet should be assumed. Seismically-induced settlement and associated ground damage for the design-event earthquake could result in unacceptable foundation movement and structural damage. Ground improvement should be incorporated into the project to mitigate potential liquefaction. Ground improvement provides mitigation of the liquefaction hazard by improving the strength, density and drainage characteristics of the soil. This can be done using variety of soil improvement techniques. Some methods are discussed in more detail below:

- Compaction Grouting Also known as Low Mobility Grouting, is a grouting technique that displaces and densifies loose granular soils and reinforces fine grained soils by the staged injection of low-slump, low mobility aggregate grout. Typically, an injection pipe is first advanced to the maximum treatment depth. The low mobility grout is then injected as the pipe is slowly extracted in lifts, creating a column of overlapping grout bulbs. The expansion of the low mobility grout bulbs displaces surrounding soils. When performed in granular soil, compaction grouting increases the surrounding soils density, friction angle and stiffness. In all soils, the high modulus grout column reinforces the soils within the treatment zone. By sequencing the compaction grouting work from primary to secondary to tertiary locations, the densification process can be performed to achieve significant improvement. Compaction is achieved above and below the water table. This method permits the use of economical continuous and spread footings. Seismic settlement and liquefaction potential are reduced.
- <u>Vibro Replacement</u> Vibro replacement is a ground improvement technique that constructs dense aggregate columns (stone columns) by means of a crane-suspended downhole vibrator, to reinforce all soils and densify granular soils. Vibro replacement stone columns are constructed with either the wet top feed process, or the dry bottom feed process. In the wet top feed process, the vibrator penetrates to the design depth by means of the vibrator's weight and vibrations, as well as water jets located in the vibrator's tip. The crushed stone is then introduced at the ground surface to the annular space around the vibrator created by the jetting water. The stone falls through the annular space to the vibrator tip, and fills the void created as the vibrator is lifted several feet. The vibrator is lowered, densifying and displacing the underlying stone. The vibro replacement process is repeated until a dense stone column is constructed to the ground surface.



The dry bottom feed process is similar except that no water jets are used and the stone is fed to the vibrator tip through a feed pipe attached to the vibrator. Predrilling of dense strata at the column location may be required for the vibrator to penetrate to the design depth. Both methods of construction create a high modulus stone column that reinforces the treatment zone and densifies surrounding granular soils. This method permits the use of economical continuous and spread footings. Seismic settlement and liquefaction potential are reduced.

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• <u>Dry Soil Mixing</u> - Dry soil mixing is a technique that improves the characteristics of soft, high moisture content clays, peats, and other weak soils, by mechanically mixing them with dry cementitious binder to create soilcrete. To construct columns, a high speed drill rig advances a drill steel with radial mixing paddles located near the bottom of the drill string. During penetration, the tool shears the soils preparing them for mixing. After the tool reaches the design depth, the binder is pumped pneumatically through the drill steel to the tool where it is mixed with the soil as the tool is withdrawn. The dry soil mixing process constructs individual soilcrete columns, rows of overlapping columns or 100% mass stabilization, all with a designed strength and stiffness. This method permits the use of economical continuous and spread footings. Seismic settlement and liquefaction potential are reduced. Dry soil mixing is low vibration, quiet, and clean, and uses readily available materials. The process is often used in high ground water conditions and has the advantage of producing practically no spoil for disposal.

The typical liquefaction mitigation methods discussed above are generally considered the most cost-effective. It is our recommendation that a contractor specializing in soil improvement be contacted to determine the most appropriate method. Other methods aimed at decreasing potential distress resulting from liquefaction can be considered on a case-by-case basis if the specifications of the proposed facility allow it.

10.3 Foundations

Subsequent to implementation of the selected ground improvement, the proposed foundations should be founded entirely in compacted fill prepared in accordance with *Section 10.1*. Recommendations for the design and construction of foundation system are presented below.

10.3.1 Design Parameters

Foundations should be designed using the geotechnical design parameters presented in the following Table 4. Footings should be designed and reinforced in accordance with the recommendations of the structural engineer and should conform to the latest edition of the California Building Code.

Table 4
Geotechnical Design Parameters For Foundations*

Foundation Dimensions	Continuous or spread foundations at least 12 inches in width and at least 15 inches below the lowest adjacent grade.	
	Concrete mat slabs should be founded a minimum of 8 inches below the lowest adjacent grade.	



Allowable Bearing Capacity (dead-plus-live load)	Compacted Fill: 1,500 pounds per square foot (psf). May be increased 300 psf for each additional foot of depth and 100 psf for each additional foot of width to a maximum of 3,000 psf.
	A one-third increase is allowed for transient live loads
	from wind or seismic forces.
Reinforcement	Reinforce in accordance with requirements as provided by the project Structural Engineer.
Allowable Coefficient of	0.30
Friction	0.10 in the event a vapor barrier is used.
	250 pounds per cubic foot (pcf) per foot of depth to a maximum of 2,500 psf.
	One third increase in passive value may be used for
Allowable Lateral Passive	wind and seismic loads.
Resistance	wind and scismic loads.
(Equivalent Fluid Pressure)	The total allowable lateral resistance may be taken as the sum of the frictional resistance and the passive resistance, provided that the passive bearing resistance does not exceed two-thirds of the total allowable resistance.

10.3.2 Settlement

Estimated settlements will depend on the foundation size and depth, and the loads imposed and the allowable bearing values used for design. For preliminary design purposes, the total static settlement for continuous or mat foundations loaded to accordance with the allowable bearing capacities recommended above is estimated to be less than 1 inch. Based on our knowledge of the project, differential static settlements are anticipated to be 0.5 inch or less.

10.3.3 Foundation Observation

To verify the presence of satisfactory materials at design elevations, footing excavations should be observed to be clean of loosened soil and debris before placing steel or concrete and probed for soft areas.

10.4 Seismic Design Parameters

Preliminary seismic design parameters for the project site were developed as per the guidelines outlined in the 2012 IBC (2008 USGS hazard data) and 2010 ASCE 7-10 Standard (with errata as of April 2013). **NV5 should be contacted to provide revisions to these parameters if other codes are specified.** The seismic design parameters for Site Class "D" were developed using a JAVA TM application, Java Ground Motion Parameter Calculator available on the USGS website (http://earthquake.usgs.gov). The preliminary seismic design parameters for the project site are presented in Table 5 below.



^{*} The above parameters assume level ground (sloping no steeper than 5 horizontal to 1 vertical).

Table 5
2012 IBC Seismic Design Parameters
And ASCE 7-10 Standard

Parameter	Value
Site Class; (Section 11.4.2)	D
Mapped Spectral Accelerations for short periods, S _S ; (Section 11.4.1)	1.492g
Mapped Spectral Accelerations for 1-sec period, S ₁ ; (Section 11.4.1)	0.543g
Site Coefficient, Fa; (Table 11.4-1)	1.000
Site Coefficient, F _v ; (Table 11.4-2)	1.500
Maximum considered earthquake spectral response acceleration for short periods, S _{MS} adjusted for Site Class (Equation 11.4-1)	1.492g
Maximum considered earthquake spectral response acceleration at 1-sec period, S_{M1} adjusted for Site Class (Equation 11.4-2)	0.814g
Five-percent damped design spectral response acceleration at short periods, S _{DS} ; (Equation 11.4-3)	0.995g
Five-percent damped design spectral response acceleration at 1-sec period, S_{D1} ; (Equation 11.4-4)	0.543g

10.5 Utility Trenching and Temporary Excavations

Excavation of the on-site soils may be achieved with conventional heavy-duty grading equipment. Temporary, unsurcharged, excavation walls may be sloped back at an inclination of 1:1(H:V) within fill and natural materials. Utility trench excavations should be shored in accordance with guidelines and regulations set forth by CalOSHA. For planning purposes, the alluvial soils may be considered a Type C soil, as defined by the current CalOSHA soil classification. Stockpiled (excavated) materials should be placed no closer to the edge of a trench excavation than a distance defined by a line drawn upward from the bottom of the trench at an inclination of 1:1(H:V), but no closer than 4 feet. All trench excavations should be made in accordance with CalOSHA requirements.

Temporary, shallow excavations with vertical side slopes less than 4 feet high will generally be stable, although due to the low density of the alluvium, there is a potential for localized sloughing. Vertical excavations greater than 4 feet high should not be attempted without proper shoring to prevent local instabilities. For vertical excavations less than about 15 feet in height, cantilevered shoring may be used. Cantilevered shoring may also be used for deeper excavations; however, the total deflection at the top of the wall should not exceed one inch. Therefore, shoring of excavations deeper than about 15 feet may need to be accomplished with the aid of tied back earth anchors.

The actual shoring design should be provided by a registered civil engineer in the State of California experienced in the design and construction of shoring under similar conditions. Once the final excavation and shoring plans are complete, the plans and the design should be reviewed by NV5 for conformance with the design intent and geotechnical recommendations. The shoring system should further satisfy requirements of CalOSHA. Shoring may be accomplished with hydraulic shores and trench plates, and/or trench boxes, soldier piles and lagging. The actual method of a shoring system should be provided and designed by a contractor experienced in installing temporary shoring under



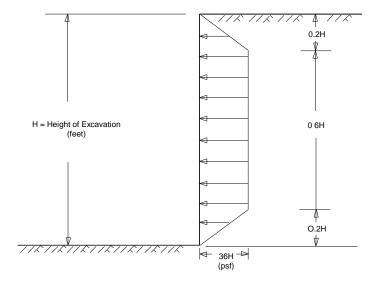
similar soil conditions. If soldier piles and lagging are to be used, we should be contacted for additional recommendations.

For major excavation or where restrictions do not permit back-sloping, shoring should be utilized in accordance with recommendations for shoring as presented in *Section 10.5.1*. Personnel from NV5 should observe the excavation so that any necessary modifications based on variations in the encountered soil conditions can be made. All applicable safety requirements and regulations, including CalOSHA requirements, should be met.

Where sloped excavations are used, the tops of the slopes should be barricaded so that vehicles and storage loads are not located within 10 feet of the tops of excavated slopes. A greater setback may be necessary when considering heavy vehicles, such as concrete trucks and cranes. NV5 should be advised of such heavy loadings so that specific setback requirements may be established. If the temporary construction slopes are to be maintained during the rainy season, berms are recommended along the tops of the slopes, to prevent runoff water from entering the excavation and eroding the slope faces.

10.5.1 Lateral Pressures

For design of cantilevered shoring, a triangular distribution of lateral earth pressure may be used. It may be assumed that the drained soils, with a level surface behind the cantilevered shoring, will exert an equivalent fluid pressure of 30 pcf. Tied-back or braced shoring should be designed to resist a trapezoidal distribution of lateral earth pressure. The recommended pressure distribution, for the case where the grade is level behind the shoring, is illustrated in the following diagram with the maximum pressure equal to 36H in psf, where H is the height of the shored wall in feet.



Any surcharge (live, including traffic, or dead load) located within a 1:1 (H:V) plane drawn upward from the base of the shored excavation should be added to the lateral earth pressures. Lateral load contributions of surcharges can be provided once the load configurations and layouts are known. As a minimum, a 2-foot equivalent soil surcharge is recommended to account for nominal construction loads.



10.6 Dewatering

Groundwater was encountered at a depth of approximately 20 feet below the existing ground surface. Dewatering is not generally anticipated during the proposed construction. However, any cases of localized seepage or heavy precipitation should be monitored during construction. If necessary, dewatering may be achieved by means of excavating a series of shallow trenches directed by gradient (i.e., gravity) to sumps with pumps. In any case, the actual means and methods of any dewatering scheme should be established by a contractor with local experience. It is important to note that temporary dewatering, if necessary, will require a permit and plan that complies with RWQCB regulations. If excessive water is encountered, NV5 should be contacted to provide additional recommendations for temporary construction dewatering. Based on the subsurface exploration and onsite percolation testing, the onsite soils maybe considered to be relatively permeable.

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10.7 Trench Bottom Stability

The bottom of onsite excavations will likely expose medium dense to dense sands to firm clayey silt. These soils should provide a suitable base for construction of pipelines. For the design of flexible conduits, a modulus of soil reaction (E'), of 2,000 pounds per square inch is recommended.

While groundwater is not anticipated to be encountered, if these soils become wet or saturated they may be prone to settlement due to construction activities such as placement and compaction of backfill soils. Buried improvements underlain by these soils could also be damaged or subjected to unacceptable settlement due to subsidence of these soils. If wet or unusually soft conditions are encountered in the trench bottom, the bottom of the excavations will need to be stabilized. A typical stabilization method includes overexcavation of the soft or saturated soil and replacement with properly compacted fill, gravel or lean concrete to form a "mat" or stable working surface in the bottom of the excavation. There are other acceptable methods that can be implemented to mitigate the presence of compressible soils or unstable trench bottom conditions, and specific recommendations for a particular alternative can be discussed based on the actual construction techniques and conditions encountered.

10.8 Pipe Bedding

It is recommended that pipe bedding materials be placed in the trench to provide uniform support and protection for the pipe. Bedding is defined as that material supporting, surrounding and extending to one foot above the top of the pipe. A cement slurry may not be used as bedding. The bedding materials should be approved by the geotechnical consultant prior to hauling on site. A minimum sixinch layer of pipe bedding should be placed beneath the pipe consisting of sand or other granular material and shall have a minimum sand equivalent of 30. This zone shall be compacted to a minimum of 90 percent relative compaction. Care should be taken by the contractor during placement of the pipe bedding so that uniform contact between the bedding and pipe is attained. There should be sufficient clearance along the side of the utility pipe or line to allow for compaction equipment. The pipe bedding and cover shall be compacted under the haunches and alongside the pipe. Mechanical compaction and hand tamping near the pipe zone should be performed carefully as to not damage the pipe.

10.9 Backfill Placement and Compaction

The majority of the on-site soils should generally be suitable for use as backfill material. Backfill should be placed in loose lifts not exceeding 8 inches in thickness and compacted to at least



90 percent (95 percent beneath or within the footprint of proposed structures) of the maximum dry density as evaluated by the latest version of ASTM D1557. Water jetting should not be used for compaction. Imported backfill should consist of granular, non-expansive soil with an Expansion Index of 20 or less and should not contain any contaminated soil, expansive soil, debris, organic matter, or other deleterious materials. The sand equivalent of the imported material shall be 20 or greater. Import material should be evaluated for suitability by the geotechnical consultant prior to transport to the site.

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The upper 12 inches of subgrade soil and all rock base should be compacted to at least 95 percent. The moisture content of the backfill should be maintained within 2 percent of optimum moisture content during compaction. All backfill should be mechanically compacted. Flooding or jetting is not recommended and should not be allowed.

10.10 Payement Sections

The following sections present recommendations for pavement of parking lots and driveways within the proposed development. For pavement within the City of Stanton or County of Orange right-of-way, the recommendations should be reviewed for compliance with the appropriate agency's ordinance.

10.10.1. Flexural Asphalt Concrete (AC) Pavement

To determine the minimum structural section an R-Value test was performed on a near surface soil sample. The test results provided an R-Value of 60; however, we assumed an R-Value of 50 for the recommended pavement sections. Pavement evaluation and design was performed in accordance with the Caltrans' "Highway Design Manual", Chapter 630 for Flexible Pavements.

The table below presents the structural sections for the assumed traffic conditions for parking areas and heavy trucks driveways (i.e. delivery trucks and garbage service trucks).

Table 7
Flexible Asphalt Pavement Sections

Davismant Aves	Traffic Index (TI)	Pavement Section				
Pavement Area	(11)	AC ⁽¹⁾ (inches)	AB ⁽²⁾ (inches)			
Parking areas	5.0	3.0	4.0			
Heavy Trucks Driveways	7.0	4.0	5.0			

⁽¹⁾ Asphalt Concrete:

Note: The upper 12-inches of subgrade soils should be compacted to at least 95% relative compaction (ASTM D 1557).

Crushed Miscellaneous Base (CMB) shall consist of broken and crushed asphalt concrete, Portland cement concrete and may contain crushed aggregate base or other rock materials. It should be uniformly mixed, moistened and compacted to 95% relative compaction (ASTM D-1557). CMB shall be in accordance with section 200-2.4 of the current edition of the Standard Specifications for Public Works Construction (Greenbook).



⁽²⁾ Crushed Miscellaneous Base (CMB), in accordance with section 200-2.4 of the Greenbook, current edition; compacted to at least 95% relative compaction (ASTM D-1557);

The asphalt concrete pavement should be compacted to 95% of the unit weight as tested in accordance with the Hveem procedure. The asphalt concrete material shall conform to Type III, Class C2 or C3, latest edition of the Greenbook Standard Specifications for Public Works Construction. An approved mix design should be submitted 30 days prior to placement. The mix design should include proportions of materials, maximum density and required lay-down temperature range. Field testing should be used to verify oil content, aggregate gradation, compacted thickness, and lay-down temperature.

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The performance of pavements is highly dependent upon providing positive surface drainage away from the edge of the pavement. The ponding of water on or adjacent to pavement areas will likely cause failure of the subgrade and resultant pavement distress. Where planters are proposed, the perimeter curb should extend at least 6 inches below the subgrade elevation of the adjacent pavement. In addition, our experience indicates that even with these provisions, a saturated subgrade condition can develop as a result of increased irrigation, landscaping and surface runoff.

10.11 Soil Corrosion

Laboratory testing was performed on a representative sample of the on-site soils to evaluate pH, minimum resistivity, and chloride and soluble sulfate content. Table 9 presents the results of the corrosivity testing.

Table 9 Corrosivity Test Results

Test Location	Exploratory Boring B-5
Depth (feet)	0 – 5
рН	8.0
Resistivity (ohm-cm)	1000
Chloride Content (ppm)	43
Soluble Sulfate Content (ppm)	120

Based on our experience and various publications including the Caltrans Corrosion Guidelines dated November 2012, the site would be considered "not corrosive" due to the chloride and sulfate concentrations. It is recommended that a corrosion specialist be contacted to determine if measures are necessary.

11.0 CONSTRUCTION OBSERVATION AND TESTING

Observation and testing of the placement and compaction of backfill, subgrade and base will be important to the performance of the proposed project. Site preparation, removal of unsuitable soils, assessment of imported fill materials, backfill placement, and other earthwork operations should be observed and tested.



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The substrata exposed during the construction may differ from that encountered in the exploratory borings. Continuous observation by a representative of NV5 during construction allows for evaluation of the soil conditions as they are encountered, and allows the opportunity to recommend appropriate revisions where necessary.

12.0 LIMITATIONS

The recommendations and opinions expressed in this report are based on NV5's review of background documents and on information obtained from field explorations. It should be noted that this study did not evaluate the possible presence of hazardous materials on any portion of the site.

Due to the limited nature of the field explorations, conditions not observed and described in this report may be present on the site. Uncertainties relative to subsurface conditions can be reduced through additional subsurface exploration. Additional subsurface evaluation and laboratory testing can be performed upon request. It should be understood that conditions different from those anticipated in this report may be encountered during construction, and that additional effort may be required to mitigate them.

Site conditions, including groundwater elevation, can change with time as a result of natural processes or the activities of man at the subject site or at nearby sites. Changes to the applicable laws, regulations, codes, and standards of practice may occur as a result of government action or the broadening of knowledge. The findings of this report may, therefore, be invalidated over time, in part or in whole, by changes over which NV5 has no control.

NV5's recommendations for this site are, to a high degree, dependent upon appropriate quality control of construction operations, placement and compaction of backfill, subgrade preparation, etc. Accordingly, the recommendations are made contingent upon the opportunity for NV5 to observe the earthwork operations for the proposed construction. If parties other than NV5 are engaged to provide such services, such parties must be notified that they will be required to assume complete responsibility as the geotechnical engineer of record for the geotechnical phase of the project by concurring with the recommendations in this report and/or by providing alternative recommendations.

This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. NV5 should be contacted if the reader requires additional information or has questions regarding the content, interpretations presented, or completeness of this document.

NV5 has endeavored to perform this geotechnical evaluation using the degree of care and skill ordinarily exercised under similar circumstances by reputable geotechnical professionals with experience in this area in similar soil conditions.

13.0 REFERENCES

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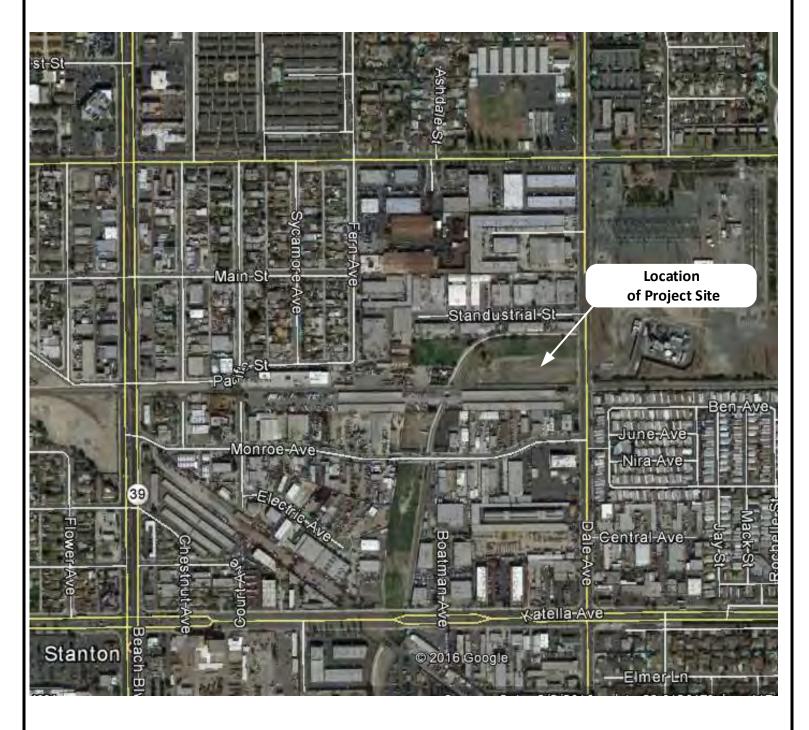
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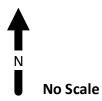
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Reference: Google Maps 2016



Not a Construction Drawing



NV5

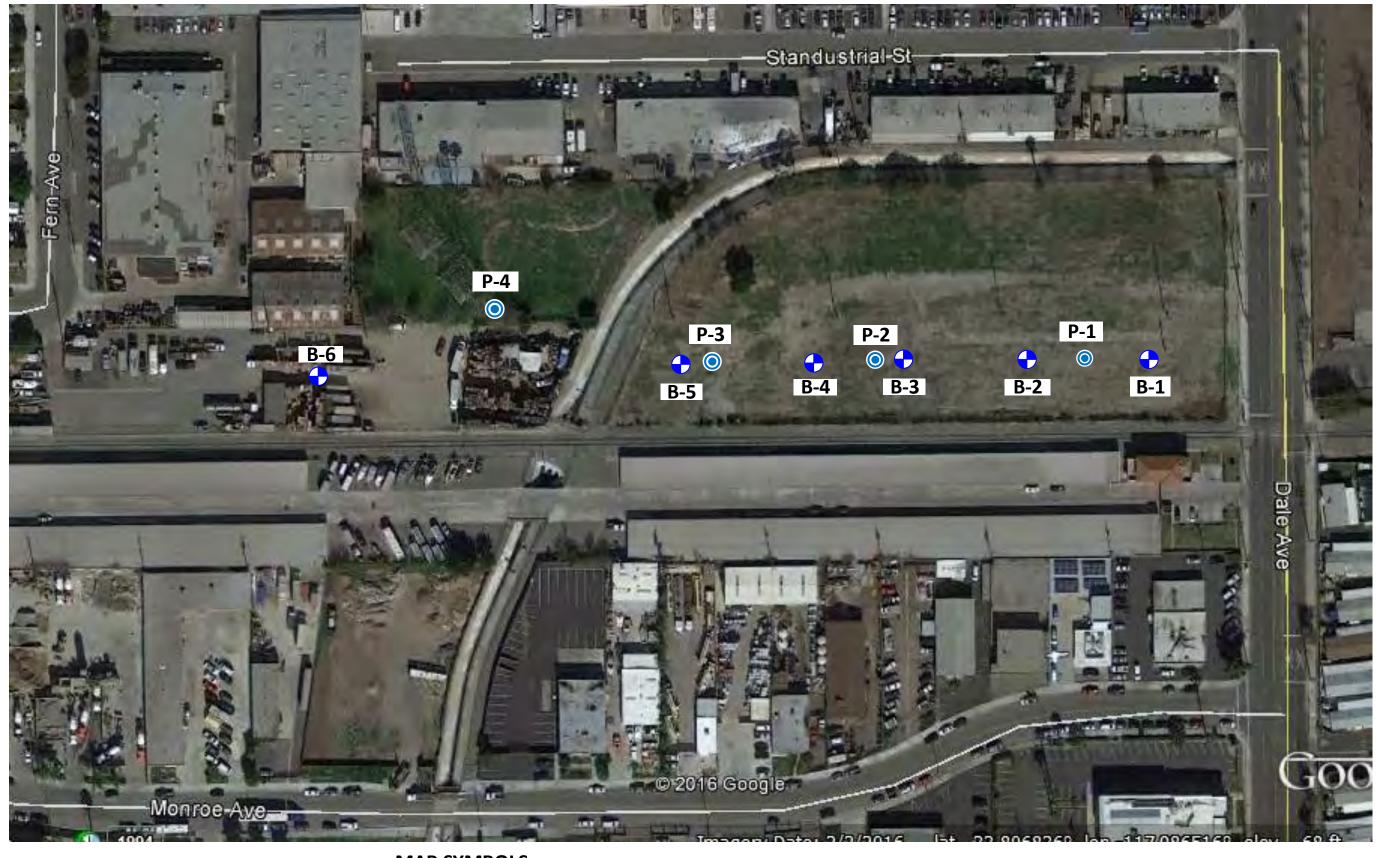
An NV5 West, Inc. Company – Offices Nationwide 10592 Avenue of Science, Suite 200 San Dlego, CA Tel: (858) 715-5800, Fax: (858) 715-5810 Project No: 113815-00763

Drawn: SR

Date: August 2016

Site Location Map
Stanton Energy Reliability Center
Stanton, California

Figure No. 1



MAP SYMBOLS

Approximate scale in feet

Approximate location of geotechnical boring

0 40 80 120 160 200

Approximate location of percolation test boring



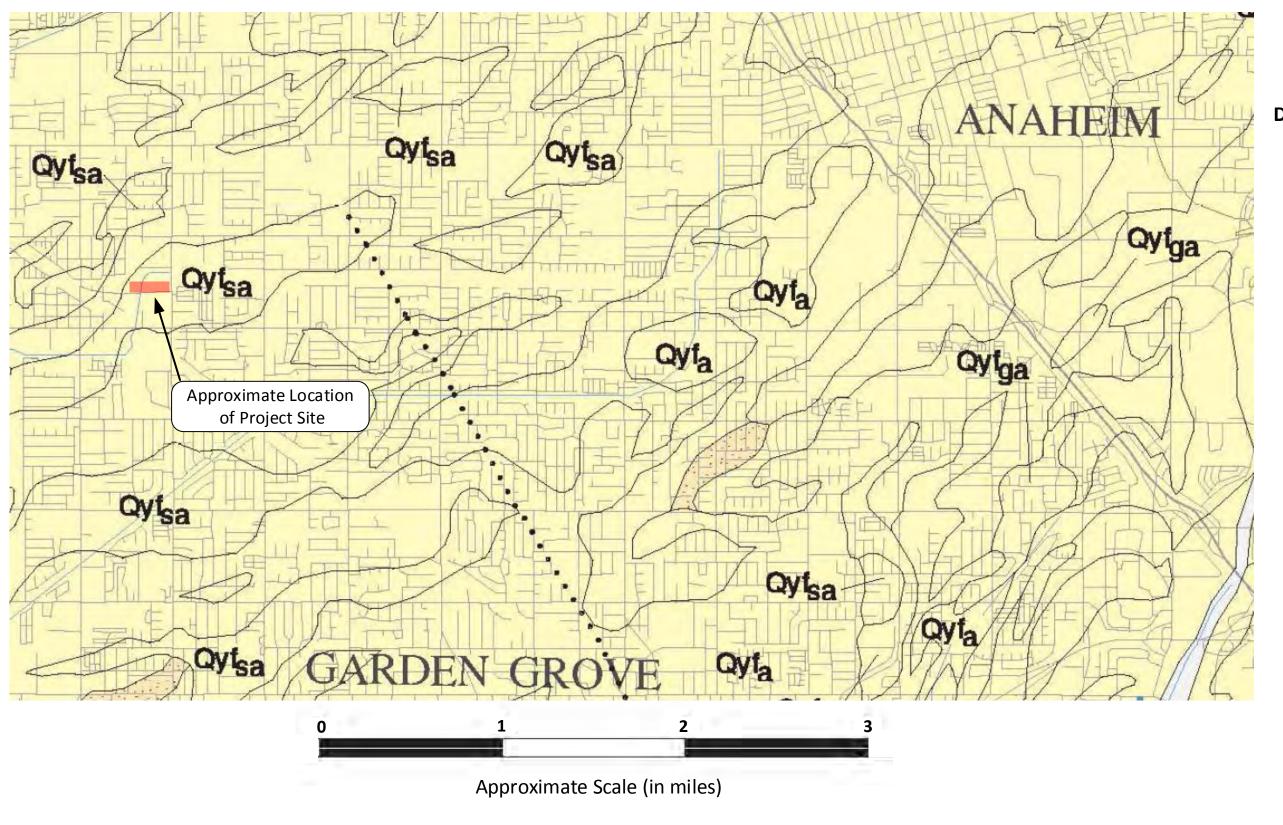


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Project No:**113815-00763**

August 2016

Geotechnical Map Stanton Energy Reliability Center Stanton, California



DESCRIPTION OF MAP UNITS

Qyf

Quaternary alluvial flood-plain deposits



Not a Construction Drawing

Reference: Geologic Map of the San Bernardino and Santa Ana 30' x 60'
Quadrangles, California. Compiled by Morton Douglas M. and Miller,
Fred K., 2006, United States Geological Survey.



NV5

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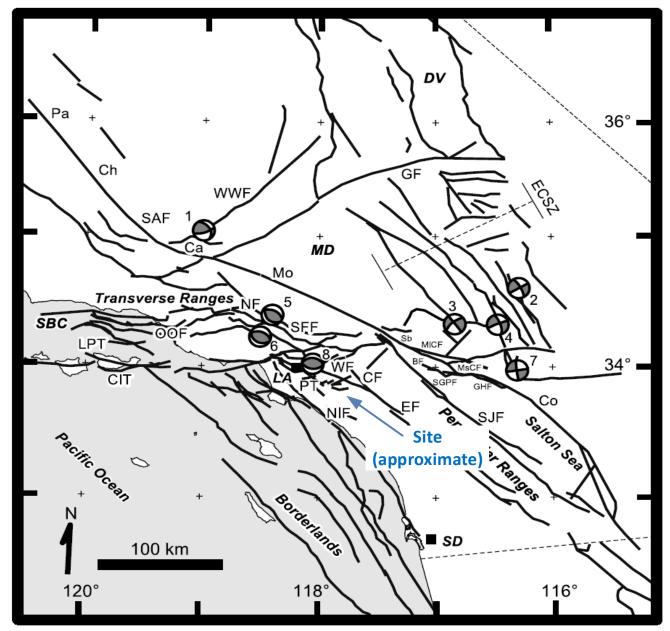
Drawn: GC

Date: September 2016

Project No: **113815-00763**

Regional Geologic Map Stanton Energy Reliability Center Stanton, California

Figure No. 3



Map of southern California showing the geographic regions, faults and focal mechanisms of the more significant earthquakes. **Regions:** Death Valley, DV; Mojave Desert MD; Los Angeles, LA; Santa Barbara Channel, SBC; and San Diego, SD. **Indicated Faults:** Banning fault, BF; Channel Island thrust, CIT; Chino fault, CF; Eastern California Shear Zone, ECSZ; Elsinore fault, EF; Garlock fault, GF; Garnet Hill fault, GHF; Lower Pitas Point thrust, LPT; Mill Creek fault, MICF; Mission Creek fault, MsCF; Northridge fault, NF; Newport Inglewood fault, NIF; offshore Oak Ridge fault, OOF; Puente Hills thrust, PT; San Andreas fault (sections: Parkfield, Pa; Cholame, Ch; Carrizo; Ca; Mojave, Mo; San Bernardino, Sb; and Coachella, Co); San Fernando fault, SFF; San Gorgonio Pass fault, SGPF; San Jacinto fault, SJF; Whittier fault, WF; and White Wolf fault, WWF. **Earthquake Focal Mechanisms:** 1952 Kern County, 1; 1999 Hector Mine, 2; 1992 Big Bear, 3; 1992 Landers, 4; 1971 San Fernando, 5; 1994 Northridge, 6; 1992 Joshua Tree, 7; and 1987 Whittier Narrows, 8.

For Schematic Use Only-Not a Construction Drawing				
NIVI5				
Regional Fault Map				
	gy Reliability Center on, California			
Drawn: GC	Contract No.: 113815-00763			
Date: September 2016	Figure No.: 4			

Reference: Plesch, Anndreas et. al., 2007, Community Fault Model (CFM) for Southern California; in the *Bulletin of the Seismological Society of America*, Vol. 97, No. 6. pp. 1793-1802, dated December.

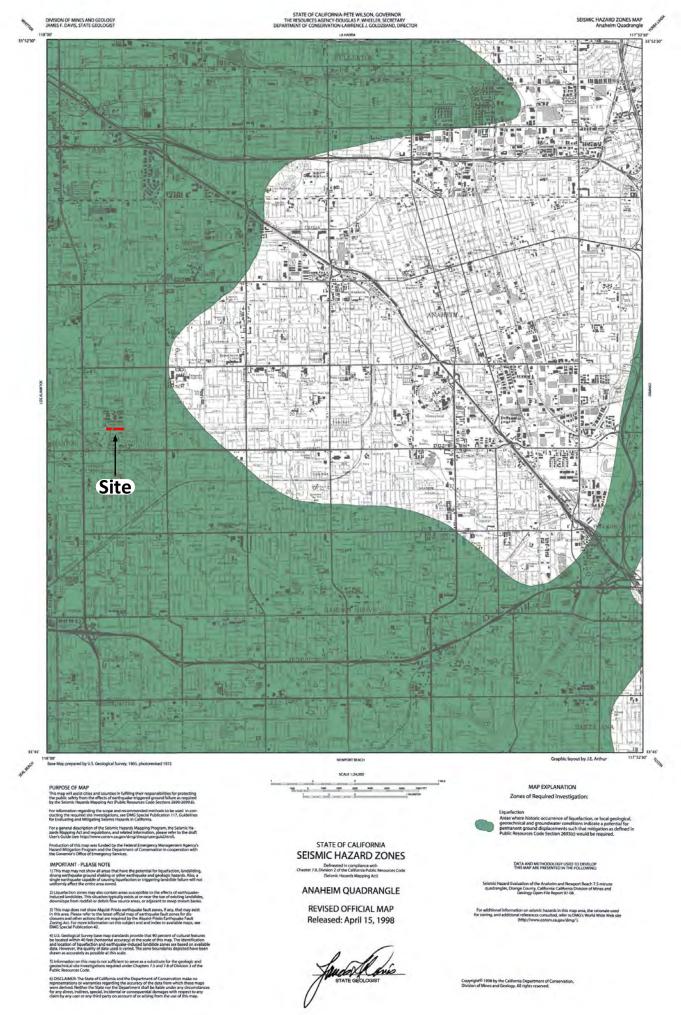
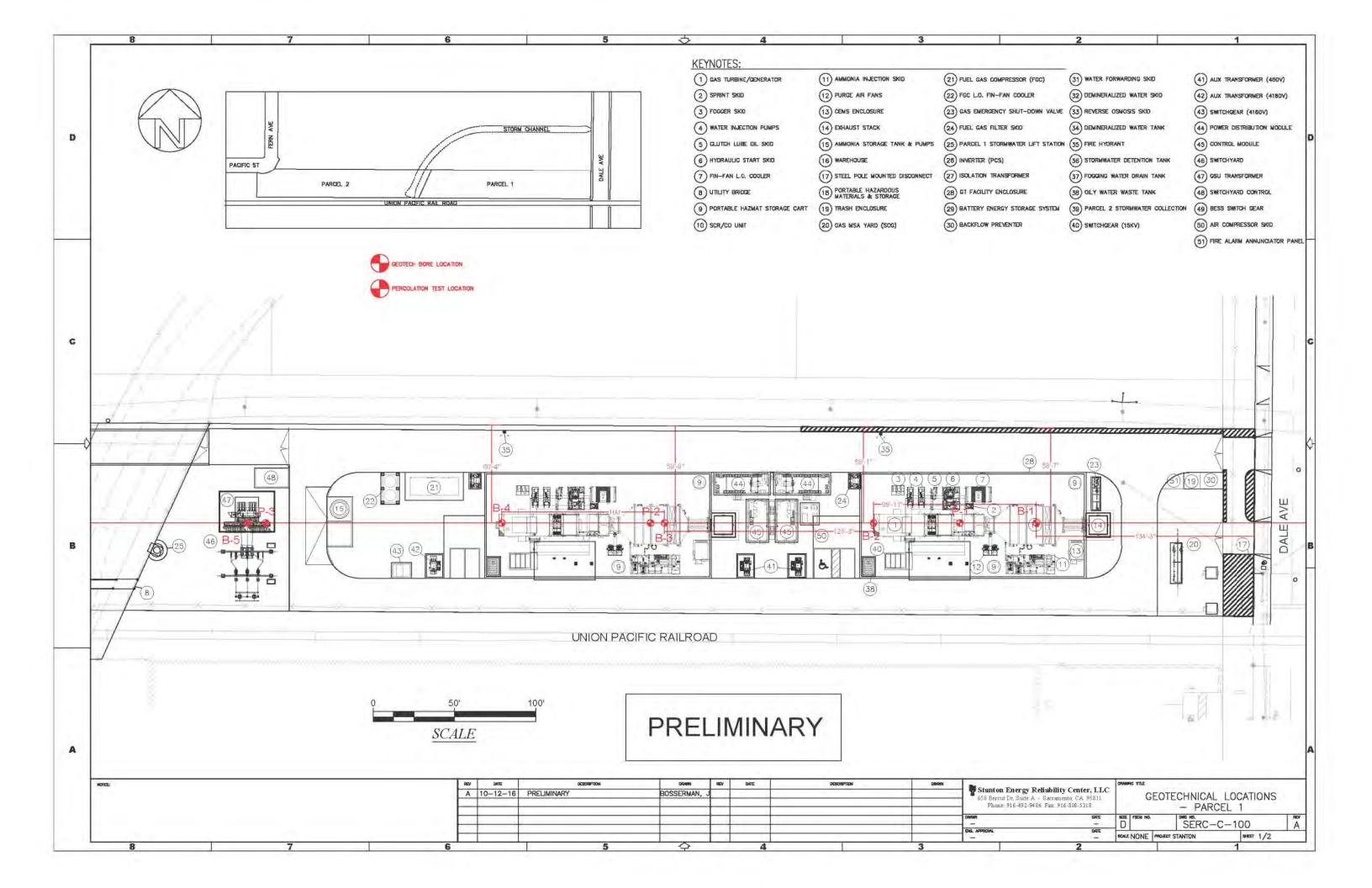
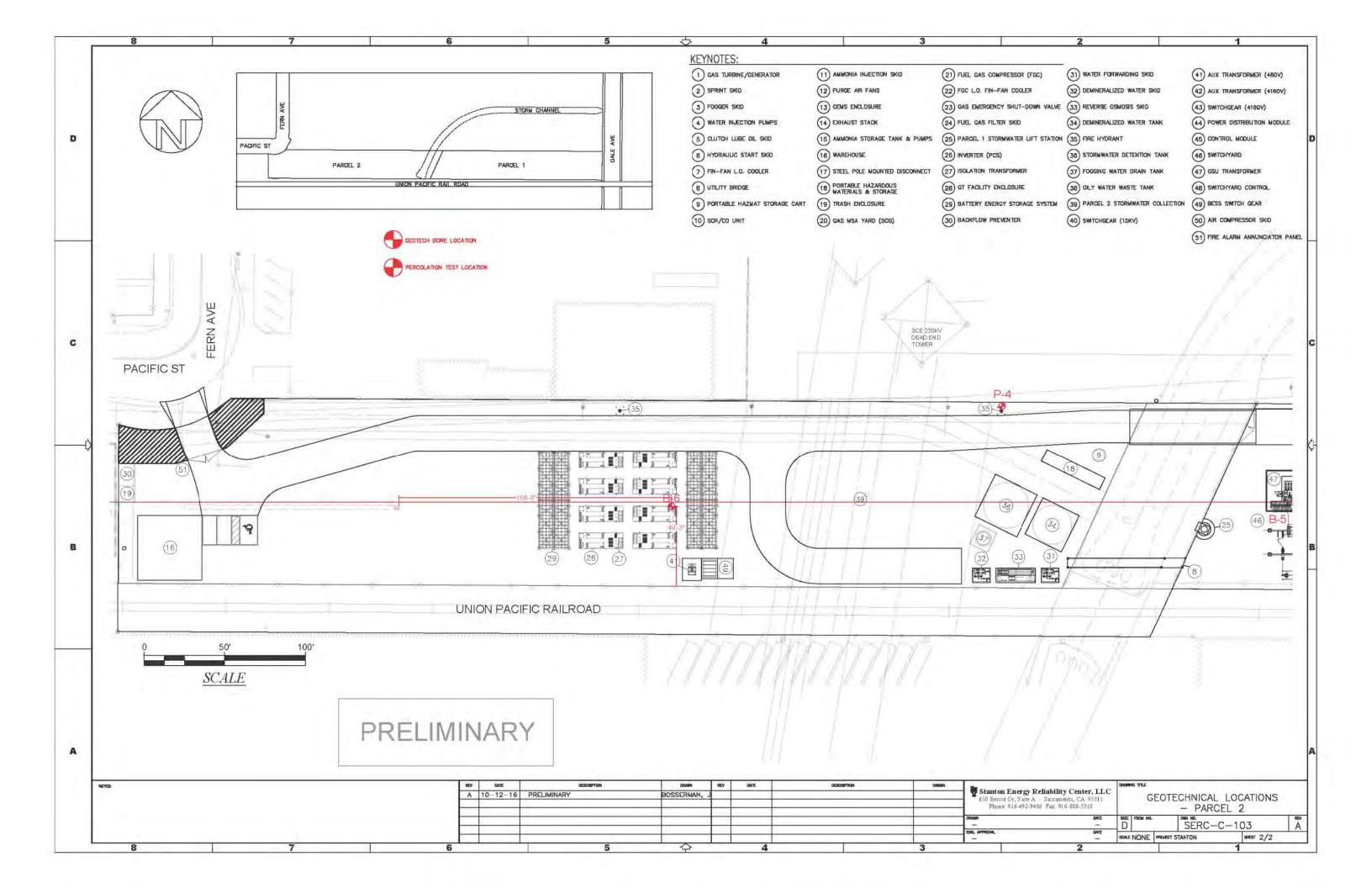


Figure 5 – Liquefaction Susceptibility Map







APPENDIX E

Table 2-2a Runoff curve numbers for urban areas 1/

Cover description		Curve numbers for hydrologic soil group					
	Average percent						
Cover type and hydrologic condition i	mpervious area 2/	A	В	C	D		
Fully developed urban areas (vegetation established)							
Open space (lawns, parks, golf courses, cemeteries, etc.) 3/:							
Poor condition (grass cover < 50%)		68	79	86	89		
Fair condition (grass cover 50% to 75%)		49	69	79	84		
Good condition (grass cover > 75%)		39	61	74	80		
Impervious areas:							
Paved parking lots, roofs, driveways, etc.							
(excluding right-of-way)		98	98	98	98		
Streets and roads:							
Paved; curbs and storm sewers (excluding							
right-of-way)		98	98	98	98		
Paved; open ditches (including right-of-way)		83	89	92	93		
Gravel (including right-of-way)		76	85	89	91		
Dirt (including right-of-way)		72	82	87	89		
Western desert urban areas:							
Natural desert landscaping (pervious areas only) 4		63	77	85	88		
Artificial desert landscaping (impervious weed barrier,							
desert shrub with 1- to 2-inch sand or gravel mulch							
and basin borders)		96	96	96	96		
Urban districts:							
Commercial and business	85	89	92	94	95		
Industrial	72	81	88	91	93		
Residential districts by average lot size:							
1/8 acre or less (town houses)		77	85	90	92		
1/4 acre		61	75	83	87		
1/3 acre	30	57	72	81	86		
1/2 acre		54	70	80	85		
1 acre		51	68	7 9	84		
2 acres	12	46	65	77	82		
Developing urban areas							
Newly graded areas							
(pervious areas only, no vegetation) 5/		77	86	91	94		
Idle lands (CN's are determined using cover types							
similar to those in table $2-2c$).							

¹ Average runoff condition, and $I_a = 0.2S$.

² The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

³ CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

⁴ Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

⁵ Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

 $\textbf{Table 2-2b} \qquad \text{Runoff curve numbers for cultivated agricultural lands } \bot$

	Cover description		Curve numbers for hydrologic soil group					
	cover description	Hydrologic		11, 01 010 610 0	on group			
Cover type	Treatment 2/	condition 3/	A	В	С	D		
Fallow	Bare soil	_	77	86	91	94		
	Crop residue cover (CR)	Poor	76	85	90	93		
		Good	74	83	88	90		
Row crops	Straight row (SR)	Poor	72	81	88	91		
-		Good	67	78	85	89		
	SR + CR	Poor	71	80	87	90		
		Good	64	75	82	85		
	Contoured (C)	Poor	70	79	84	88		
		Good	65	75	82	86		
	C + CR	Poor	69	78	83	87		
		Good	64	74	81	85		
	Contoured & terraced (C&T)	Poor	66	74	80	82		
		Good	62	71	78	81		
	C&T+ CR	Poor	65	73	79	81		
		Good	61	70	77	80		
Small grain	SR	Poor	65	76	84	88		
		Good	63	7 5	83	87		
	SR + CR	Poor	64	75	83	86		
		Good	60	72	80	84		
	C	Poor	63	74	82	85		
		Good	61	73	81	84		
	C + CR	Poor	62	73	81	84		
		Good	60	72	80	83		
	C&T	Poor	61	72	79	82		
		Good	59	70	78	81		
	C&T+ CR	Poor	60	71	78	81		
		Good	58	69	77	80		
Close-seeded	SR	Poor	66	77	85	89		
or broadcast	_	Good	58	72	81	85		
legumes or	C	Poor	64	75	83	85		
rotation		Good	55	69	78	83		
meadow	C&T	Poor	63	73	80	83		
		Good	51	67	76	80		

 $^{^{1}}$ Average runoff condition, and I_a =0.2S

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

² Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

 $^{^3}$ Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good \geq 20%), and (e) degree of surface roughness.

Table 2-2cRunoff curve numbers for other agricultural lands $\underline{1}$

Cover description		Curve numbers for hydrologic soil group				
•	Hydrologic		ily arotogic son group			
Cover type	condition	A	В	С	D	
Pasture, grassland, or range—continuous	Poor	68	79	86	89	
forage for grazing. 2/	Fair	49	69	79	84	
	Good	39	61	74	80	
Meadow—continuous grass, protected from grazing and generally mowed for hay.	_	30	58	71	78	
Brush—brush-weed-grass mixture with brush	Poor	48	67	77	83	
the major element. 3/	Fair	35	56	70	77	
	Good	30 4/	48	65	73	
Woods—grass combination (orchard	Poor	57	73	82	86	
or tree farm). 5/	Fair	43	65	76	82	
	Good	32	58	72	79	
Woods. 6/	Poor	45	66	77	83	
	Fair	36	60	73	79	
	Good	30 4/	55	70	77	
Farmsteads—buildings, lanes, driveways, and surrounding lots.	_	59	74	82	86	

¹ Average runoff condition, and $I_a = 0.2S$.

Poor: <50%) ground cover or heavily grazed with no mulch.</p>

Fair: 50 to 75% ground cover and not heavily grazed.

Good: > 75% ground cover and lightly or only occasionally grazed.

³ *Poor*: <50% ground cover.

Fair: 50 to 75% ground cover.

Good: >75% ground cover.

⁴ Actual curve number is less than 30; use CN = 30 for runoff computations.

⁵ CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

⁶ Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.

Fair: Woods are grazed but not burned, and some forest litter covers the soil.

Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 2-2d Runoff curve numbers for arid and semiarid rangelands $\underline{1}$

Cover description			Curve numbers for ———— hydrologic soil group ———				
Cover type	Hydrologic condition 2/	A 3/	В	С	D		
Herbaceous—mixture of grass, weeds, and	Poor		80	87	93		
low-growing brush, with brush the	Fair		71	81	89		
minor element.	Good		62	74	85		
Oak-aspen—mountain brush mixture of oak brush,	Poor		66	74	79		
aspen, mountain mahogany, bitter brush, maple,	Fair		48	57	63		
and other brush.	Good		30	41	48		
Pinyon-juniper—pinyon, juniper, or both;	Poor		75	85	89		
grass understory.	Fair		58	73	80		
	Good		41	61	71		
Sagebrush with grass understory.	Poor		67	80	85		
	Fair		51	63	70		
	Good		35	47	55		
Desert shrub—major plants include saltbush,	Poor	63	77	85	88		
greasewood, creosotebush, blackbrush, bursage,	Fair	55	72	81	86		
palo verde, mesquite, and cactus.	Good	49	68	79	84		

 $^{^{\, 1}}$ $\,$ Average runoff condition, and $I_a,$ = 0.2S. For range in humid regions, use table 2-2c.

Poor: <30% ground cover (litter, grass, and brush overstory).
 Fair: 30 to 70% ground cover.

Good: > 70% ground cover.

 $^{^{\}rm 3}$ $\,$ Curve numbers for group A have been developed only for desert shrub.



APPENDIX F

Western Subcatchment Existing System

************************** RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE (Reference: 1986 ORANGE COUNTY HYDROLOGY CRITERION) (c) Copyright 1983-2014 Advanced Engineering Software (aes) Ver. 21.0 Release Date: 06/01/2014 License ID 1501 FILE NAME: C:\USERS\ENRIGHTP\DESKTOP\TEMP\XWEST.DAT TIME/DATE OF STUDY: 14:21 10/07/2016 ______ USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION: ______ --*TIME-OF-CONCENTRATION MODEL*--USER SPECIFIED STORM EVENT(YEAR) = 100.00 SPECIFIED MINIMUM PIPE SIZE(INCH) = 6.00 SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE = 0.90 *DATA BANK RAINFALL USED* *ANTECEDENT MOISTURE CONDITION (AMC) III ASSUMED FOR RATIONAL METHOD* *USER-DEFINED STREET-SECTIONS FOR COUPLED PIPEFLOW AND STREETFLOW MODEL* HALF- CROWN TO STREET-CROSSFALL: CURB GUTTER-GEOMETRIES: MANNING WIDTH CROSSFALL IN- / OUT-/PARK- HEIGHT WIDTH LIP HIKE FACTOR NO. (FT) (FT) SIDE / SIDE / WAY (FT) (FT) (FT) (FT) 1 30.0 20.0 0.018/0.018/0.020 0.67 2.00 0.0313 0.167 0.0150 GLOBAL STREET FLOW-DEPTH CONSTRAINTS: 1. Relative Flow-Depth = 0.00 FEET as (Maximum Allowable Street Flow Depth) - (Top-of-Curb) 2. (Depth)*(Velocity) Constraint = 6.0 (FT*FT/S) *SIZE PIPE WITH A FLOW CAPACITY GREATER THAN OR EQUAL TO THE UPSTREAM TRIBUTARY PIPE.* *USER-SPECIFIED MINIMUM TOPOGRAPHIC SLOPE ADJUSTMENT NOT SELECTED FLOW PROCESS FROM NODE 100.00 TO NODE 101.00 IS CODE = 21 >>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS< >>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<< _____ INITIAL SUBAREA FLOW-LENGTH(FEET) = 216.00

```
ELEVATION DATA: UPSTREAM(FEET) = 69.10 DOWNSTREAM(FEET) = 68.70
Tc = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]**0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 9.186
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 4.367
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                      Ap SCS Tc
  LAND USE
               GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
COMMERCIAL
                      0.43 0.40 0.100 52 9.19
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.100
SUBAREA RUNOFF(CFS) = 1.67
TOTAL AREA(ACRES) = 0.43 PEAK FLOW RATE(CFS) = 1.67
  **************************
FLOW PROCESS FROM NODE 101.00 TO NODE 102.00 IS CODE = 41
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<
______
ELEVATION DATA: UPSTREAM(FEET) = 66.20 DOWNSTREAM(FEET) = 65.65
FLOW LENGTH(FEET) = 62.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 24.0 INCH PIPE IS 4.7 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 3.90
GIVEN PIPE DIAMETER(INCH) = 24.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
                1.67
PIPE TRAVEL TIME(MIN.) = 0.27 Tc(MIN.) = 9.45
LONGEST FLOWPATH FROM NODE 100.00 TO NODE 102.00 = 278.00 FEET.
FLOW PROCESS FROM NODE 102.00 TO NODE 202.00 IS CODE = 41
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<
______
ELEVATION DATA: UPSTREAM(FEET) = 65.50 DOWNSTREAM(FEET) = 65.02
FLOW LENGTH(FEET) = 163.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 36.0 INCH PIPE IS 5.4 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 2.51
GIVEN PIPE DIAMETER(INCH) = 36.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
                1.67
```

PIPE TRAVEL TIME(MIN.) = 1.08 Tc(MIN.) = 10.53

LONGEST FLOWPATH FROM NODE 100.00 TO NODE 202.00 = 441.00 FEET.

```
FLOW PROCESS FROM NODE 202.00 TO NODE 202.00 IS CODE = 1
______
>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<
______
TOTAL NUMBER OF STREAMS = 2
CONFLUENCE VALUES USED FOR INDEPENDENT STREAM 1 ARE:
TIME OF CONCENTRATION(MIN.) = 10.53
RAINFALL INTENSITY(INCH/HR) = 4.04
AREA-AVERAGED Fm(INCH/HR) = 0.04
AREA-AVERAGED Fp(INCH/HR) = 0.40
AREA-AVERAGED Ap = 0.10
EFFECTIVE STREAM AREA(ACRES) = 0.43
TOTAL STREAM AREA(ACRES) = 0.43
PEAK FLOW RATE(CFS) AT CONFLUENCE =
FLOW PROCESS FROM NODE 200.00 TO NODE 201.00 IS CODE = 21
>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<
>>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<<
______
INITIAL SUBAREA FLOW-LENGTH(FEET) = 195.00
ELEVATION DATA: UPSTREAM(FEET) = 69.90 DOWNSTREAM(FEET) = 68.50
Tc = K^*[(LENGTH^{**} 3.00)/(ELEVATION CHANGE)]^{**}0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 6.725
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 5.221
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                    Ap SCS Tc
  LAND USE
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
COMMERCIAL
                Α
                    0.81
                         0.40 0.100 52 6.72
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.100
SUBAREA RUNOFF(CFS) = 3.76
TOTAL AREA(ACRES) = 0.81 PEAK FLOW RATE(CFS) = 3.76
**************************
FLOW PROCESS FROM NODE 201.00 TO NODE 202.00 IS CODE = 41
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT) <<<<
______
ELEVATION DATA: UPSTREAM(FEET) = 66.60 DOWNSTREAM(FEET) = 65.90
```

FLOW LENGTH(FEET) = 81.00 MANNING'S N = 0.013

ASSUME FULL-FLOWING PIPELINE

PIPE-FLOW VELOCITY(FEET/SEC.) = 3.05

(PIPE FLOW VELOCITY CORRESPONDING TO FULL PIPE CAPACITY FLOW)

GIVEN PIPE DIAMETER(INCH) = 8.00 NUMBER OF PIPES = 1

PIPE-FLOW(CFS) = 3.76

PIPE TRAVEL TIME(MIN.) = 0.44 Tc(MIN.) = 7.17

LONGEST FLOWPATH FROM NODE 200.00 TO NODE 202.00 = 276.00 FEET.

FLOW PROCESS FROM NODE 202.00 TO NODE 202.00 IS CODE = 1

>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<

TOTAL NUMBER OF STREAMS = 2

CONFLUENCE VALUES USED FOR INDEPENDENT STREAM 2 ARE:

TIME OF CONCENTRATION(MIN.) = 7.17

RAINFALL INTENSITY(INCH/HR) = 5.03

AREA-AVERAGED Fm(INCH/HR) = 0.04

AREA-AVERAGED Fp(INCH/HR) = 0.40

AREA-AVERAGED Ap = 0.10

EFFECTIVE STREAM AREA(ACRES) = 0.81

TOTAL STREAM AREA(ACRES) = 0.81

PEAK FLOW RATE(CFS) AT CONFLUENCE = 3.76

** CONFLUENCE DATA **

STREAM Q Tc Intensity Fp(Fm) Ap Ae HEADWATER NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE

- 1 1.67 10.53 4.037 0.40(0.04) 0.10 0.4 100.00
- 2 3.76 7.17 5.034 0.40(0.04) 0.10 0.8 200.00

RAINFALL INTENSITY AND TIME OF CONCENTRATION RATIO CONFLUENCE FORMULA USED FOR 2 STREAMS.

** PEAK FLOW RATE TABLE **

STREAM Q Tc Intensity Fp(Fm) Ap Ae HEADWATER NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE

- 1 5.19 7.17 5.034 0.40(0.04) 0.10 1.1 200.00
- 2 4.69 10.53 4.037 0.40(0.04) 0.10 1.2 100.00

COMPUTED CONFLUENCE ESTIMATES ARE AS FOLLOWS:

PEAK FLOW RATE(CFS) = 5.19 Tc(MIN.) = 7.17

EFFECTIVE AREA(ACRES) = 1.10 AREA-AVERAGED Fm(INCH/HR) = 0.04

```
AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.10
TOTAL AREA(ACRES) =
                  1.2
LONGEST FLOWPATH FROM NODE 100.00 TO NODE 202.00 = 441.00 FEET.
   *************************
FLOW PROCESS FROM NODE 202.00 TO NODE 205.00 IS CODE = 41
   ______
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<
______
ELEVATION DATA: UPSTREAM(FEET) = 64.92 DOWNSTREAM(FEET) = 64.07
FLOW LENGTH(FEET) = 288.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 36.0 INCH PIPE IS 9.4 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 3.50
GIVEN PIPE DIAMETER(INCH) = 36.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
              5.19
PIPE TRAVEL TIME(MIN.) = 1.37 Tc(MIN.) = 8.54
LONGEST FLOWPATH FROM NODE 100.00 TO NODE 205.00 = 729.00 FEET.
*************************
FLOW PROCESS FROM NODE 205.00 TO NODE 205.00 IS CODE = 1
>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<
______
TOTAL NUMBER OF STREAMS = 2
CONFLUENCE VALUES USED FOR INDEPENDENT STREAM 1 ARE:
TIME OF CONCENTRATION(MIN.) = 8.54
RAINFALL INTENSITY(INCH/HR) = 4.55
AREA-AVERAGED Fm(INCH/HR) = 0.04
AREA-AVERAGED Fp(INCH/HR) = 0.40
AREA-AVERAGED Ap = 0.10
EFFECTIVE STREAM AREA(ACRES) = 1.10
TOTAL STREAM AREA(ACRES) =
                      1.24
PEAK FLOW RATE(CFS) AT CONFLUENCE =
                              5.19
*************************
FLOW PROCESS FROM NODE 203.00 TO NODE 204.00 IS CODE = 21
>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<
>>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<<
______
INITIAL SUBAREA FLOW-LENGTH(FEET) = 189.00
ELEVATION DATA: UPSTREAM(FEET) = 75.30 DOWNSTREAM(FEET) = 68.30
```

```
Tc = K^*[(LENGTH^{**} 3.00)/(ELEVATION CHANGE)]^{**}0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 5.000
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 6.187
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                     Ap SCS Tc
  LAND USE
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
                     0.78  0.40  0.100  52  5.00
COMMERCIAL
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.100
SUBAREA RUNOFF(CFS) = 4.32
TOTAL AREA(ACRES) = 0.78 PEAK FLOW RATE(CFS) = 4.32
**************************
FLOW PROCESS FROM NODE 204.00 TO NODE 205.00 IS CODE = 41
   _____
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<
______
ELEVATION DATA: UPSTREAM(FEET) = 65.50 DOWNSTREAM(FEET) = 65.20
FLOW LENGTH(FEET) = 63.00 MANNING'S N = 0.013
ASSUME FULL-FLOWING PIPELINE
PIPE-FLOW VELOCITY(FEET/SEC.) = 2.26
(PIPE FLOW VELOCITY CORRESPONDING TO FULL PIPE CAPACITY FLOW)
GIVEN PIPE DIAMETER(INCH) = 8.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
              4.32
PIPE TRAVEL TIME(MIN.) = 0.46 Tc(MIN.) = 5.46
LONGEST FLOWPATH FROM NODE 203.00 TO NODE 205.00 = 252.00 FEET.
*******************************
FLOW PROCESS FROM NODE 205.00 TO NODE 205.00 IS CODE = 1
_____
>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<>>>
>>>>AND COMPUTE VARIOUS CONFLUENCED STREAM VALUES<
______
TOTAL NUMBER OF STREAMS = 2
CONFLUENCE VALUES USED FOR INDEPENDENT STREAM 2 ARE:
TIME OF CONCENTRATION(MIN.) = 5.46
RAINFALL INTENSITY(INCH/HR) = 5.88
AREA-AVERAGED Fm(INCH/HR) = 0.04
AREA-AVERAGED Fp(INCH/HR) = 0.40
AREA-AVERAGED Ap = 0.10
EFFECTIVE STREAM AREA(ACRES) =
                           0.78
TOTAL STREAM AREA(ACRES) =
PEAK FLOW RATE(CFS) AT CONFLUENCE =
```

** CONFLUENCE DATA **

STREAM Q Tc Intensity Fp(Fm) Ap Ae HEADWATER NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE

- 1 5.19 8.54 4.554 0.40(0.04) 0.10 1.1 200.00
- 1 4.69 11.94 3.757 0.40(0.04) 0.10 1.2 100.00
- 2 4.32 5.46 5.881 0.40(0.04) 0.10 0.8 203.00

RAINFALL INTENSITY AND TIME OF CONCENTRATION RATIO CONFLUENCE FORMULA USED FOR 2 STREAMS.

** PEAK FLOW RATE TABLE **

STREAM Q Tc Intensity Fp(Fm) Ap Ae HEADWATER NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE

- 1 8.62 5.46 5.881 0.40(0.04) 0.10 1.5 203.00
- 2 8.53 8.54 4.554 0.40(0.04) 0.10 1.9 200.00
- 3 7.44 11.94 3.757 0.40(0.04) 0.10 2.0 100.00

COMPUTED CONFLUENCE ESTIMATES ARE AS FOLLOWS:

PEAK FLOW RATE(CFS) = 8.62 Tc(MIN.) = 5.46

EFFECTIVE AREA(ACRES) = 1.48 AREA-AVERAGED Fm(INCH/HR) = 0.04

AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.10

TOTAL AREA(ACRES) = 2.0

LONGEST FLOWPATH FROM NODE 100.00 TO NODE 205.00 = 729.00 FEET.

FLOW PROCESS FROM NODE 205.00 TO NODE 206.00 IS CODE = 41

>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<>>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<>>>>

ELEVATION DATA: UPSTREAM(FEET) = 63.97 DOWNSTREAM(FEET) = 63.60

FLOW LENGTH(FEET) = 124.00 MANNING'S N = 0.013

DEPTH OF FLOW IN 36.0 INCH PIPE IS 12.2 INCHES

PIPE-FLOW VELOCITY(FEET/SEC.) = 4.06

GIVEN PIPE DIAMETER(INCH) = 36.00 NUMBER OF PIPES = 1

PIPE-FLOW(CFS) = 8.62

PIPE TRAVEL TIME(MIN.) = 0.51 Tc(MIN.) = 5.97

LONGEST FLOWPATH FROM NODE 100.00 TO NODE 206.00 = 853.00 FEET.

END OF STUDY SUMMARY:

TOTAL AREA(ACRES) = 2.0 TC(MIN.) = 5.97

EFFECTIVE AREA(ACRES) = 1.48 AREA-AVERAGED Fm(INCH/HR)= 0.04

AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.100

PEAK FLOW RATE(CFS) = 8.62

** PEAK FLOW RATE TABLE **

STREAM Q Tc Intensity Fp(Fm) Ap Ae HEADWATER NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE

- 1 8.62 5.97 5.588 0.40(0.04) 0.10 1.5 203.00
- 2 8.53 9.05 4.405 0.40(0.04) 0.10 1.9 200.00
- 3 7.44 12.47 3.664 0.40(0.04) 0.10 2.0 100.00

END OF RATIONAL METHOD ANALYSIS

NO		WATERSHED AREA-A RACTION ESTIMATION		DSS RATE (Fm)
	======================================	======================================		 (aes)
		e: 06/01/2014 Licer		
****** 		******	******* 	*********
Problem	Descriptions:			
	inage Study			
Existing	Condition			
West				
	HOMOGENEOUS WA	========= ATERSHED AREA-AV ESTIMATIONS FOR A	ERAGED LOS	S RATE (Fm)
AND LC	HOMOGENEOUS WA W LOSS FRACTION E 4-HOUR DURATION VER AREA PER	ATERSHED AREA-AV	ERAGED LOS .MC III: 5.63 (inche VE LOSS RA	S RATE (Fm) es) TE
AND LC	HOMOGENEOUS WA W LOSS FRACTION E 4-HOUR DURATION VER AREA PER (Acres) PERVIOU	ATERSHED AREA-AVESTIMATIONS FOR A I RAINFALL DEPTH = CENT OF SCS CUR	ERAGED LOS .MC III: 5.63 (inch VE LOSS RA Fp(in./hr.)	S RATE (Fm) es) TE
AND LC TOTAL: SOIL-CC TYPE 1	HOMOGENEOUS WARD LOSS FRACTION E 4-HOUR DURATION VER AREA PER (Acres) PERVIOU 0.43 2.00 9	ATERSHED AREA-AVESTIMATIONS FOR A I RAINFALL DEPTH = CENT OF SCS CUR	ERAGED LOS MC III: 5.63 (inche VE LOSS RA' Fp(in./hr.) 0.958	S RATE (Fm) es) TE
AND LO TOTAL: SOIL-CO TYPE 1	HOMOGENEOUS WARD LOSS FRACTION E 4-HOUR DURATION VER AREA PER (Acres) PERVIOU 0.43 2.00 9 0.81 2.00 9	ATERSHED AREA-AVESTIMATIONS FOR A I RAINFALL DEPTH = CENT OF SCS CUR IS AREA NUMBER 198.(AMC II) 10.000	ERAGED LOS MC III: 5.63 (incher VE LOSS RAF Fp(in./hr.) 0.958 0.958	S RATE (Fm) es) TE
SOIL-CO TYPE 1 2 3	HOMOGENEOUS WARD LOSS FRACTION E 4-HOUR DURATION VER AREA PER (Acres) PERVIOU 0.43 2.00 9 0.81 2.00 9	ATERSHED AREA-AVESTIMATIONS FOR ASSETTIMATIONS FOR ASSETTIMATIONS FOR ASSETTIMATIONS FOR ASSETTIMATIONS FOR ASSETTIMATIONS FOR ASSETTIMATION A	ERAGED LOS MC III: 5.63 (incher VE LOSS RAF Fp(in./hr.) 0.958 0.958	S RATE (Fm) es) TE
SOIL-CO TYPE 1 2 3 TOTAL	HOMOGENEOUS WAREA (Acres) PERVIOU 0.43 2.00 9 0.78 2.0	ATERSHED AREA-AVESTIMATIONS FOR ASSETTIMATIONS FOR ASSETTIMATIONS FOR ASSETTIMATIONS FOR ASSETTIMATIONS FOR ASSETTIMATIONS FOR ASSETTIMATION A	ERAGED LOS MC III: 5.63 (inche VE LOSS RA Fp(in./hr.) 0.958 0.958 0.958	S RATE (Fm) es) TE

	ALL AREA UN					*********
						=======================================
(C) Copyrig	ht 1989-201	4 Advan	ced Engi	neerin	g Softw	vare (aes)
Ver. 21.0	Release Da	te: 06/0	1/2014	Licens	e ID 15	01
******	******	*****	*****	*****	*****	********
Problem Descri	ptions:					
SERC Drainage	•					
Existing Condit	•					
West						
RATIONAL MI	THOD CALIB	RATION	COEFFI	CIENT =	= 0.79	
TOTAL CATCH						
SOIL-LOSS RA		-				
LOW LOSS FR	ACTION = 0.0)42				
TIME OF CON	CENTRATION	I(MIN.) =	= 5.97			
SMALL AREA	PEAK Q COM	PUTED (JSING P	EAK FL	OW RA	TE FORMULA
ORANGE COL	NTY "VALLEY	/" RAINF	ALL VAL	UES AF	RE USEI	D
RETURN FREC	QUENCY(YEAI	RS) = 100)			
5-MINUTE F	OINT RAINF	ALL VALU	JE(INCH	ES) = 0).52	
30-MINUTE	POINT RAINF	ALL VAL	UE(INCH	IES) =	1.09	
1-HOUR PO	DINT RAINFA	LL VALUI	E(INCHE	S) = 1.	45	
3-HOUR PO	DINT RAINFA	LL VALUI	E(INCHE	S) = 2.	43	
6-HOUR PO	DINT RAINFA	LL VALUI	E(INCHE	S) = 3.	36	
24-HOUR P	OINT RAINFA	LL VALU	E(INCH	ES) = 5	.63	
TOTAL CATCH	MENT RUN	OFF VO	LUME(A	CRE-FE	EET) =	0.71
TOTAL CATCH			-		-	0.24

TIME VOLUM (HOURS) (AF)	-•	2.5	5.0	7.5	10.0	
(1100KS) (AF)	(CF3) 					
0.08 0.0005	0.13 Q					
	0.42.0					
0.18 0.0016	0.13 Q	•		•		
0.18 0.0016 0.28 0.0027	-			•		

0.48	0.0050	0.14 Q	•		•	•	
0.58	0.0061	0.14 Q	•			•	
0.68	0.0072	0.14 Q					
0.78	0.0083	0.14 Q					
0.88	0.0094	0.14 Q				•	
0.98	0.0106	0.14 Q					
1.08	0.0117	0.14 Q					
1.17	0.0129	0.14 Q				•	
1.27	0.0140	0.14 Q					
1.37	0.0151	0.14 Q				•	
1.47	0.0163	0.14 Q					
1.57	0.0175	0.14 Q					
1.67	0.0186	0.14 Q					
1.77	0.0198	0.14 Q					
1.87	0.0210	0.14 Q	•				
1.97	0.0222	0.14 Q					
2.07	0.0233	0.14 Q					
2.17	0.0245	0.15 Q					
2.27	0.0257	0.15 Q					
2.37	0.0269	0.15 Q					
2.47	0.0281	0.15 Q					
2.57	0.0294	0.15 Q				_	
2.67	0.0306	0.15 Q				_	
2.77	0.0318	0.15 Q					
2.87	0.0330	0.15 Q				_	
2.97	0.0343	0.15 Q					
3.07	0.0355	0.15 Q	•	·	·		
3.16	0.0368	0.15 Q					
3.26	0.0380	0.15 Q		·	į		
3.36	0.0393	0.15 Q	•	·	•	•	
3.46	0.0405	0.15 Q	•	·	•	•	
3.56	0.0418	0.16 Q	•	•	•	•	
3.66	0.0431	0.16 Q	•	•	•	•	
3.76	0.0444	0.16 Q	•	•	•	•	
3.86	0.0457	0.16 Q 0.16 Q	•	•	•	•	
3.96	0.0437	0.16 Q 0.16 Q	•	•	•	•	
4.06	0.0470	0.16 Q 0.16 Q	•	•	•	•	
4.16	0.0483	0.16 Q 0.16 Q	•	•	•	•	
4.16	0.0490	0.16 Q 0.16 Q	•	•	•	•	
4.26	0.0522	0.16 Q 0.16 Q	•	•	•	•	
		-	•	•	•	•	
4.46 4.56	0.0536	0.16 Q	•	•	•	•	
4.56	0.0549	0.16 Q	•	•	•	•	
4.66	0.0563	0.16 Q	•	•	•	•	
4.76	0.0576	0.17 Q	•	•	•	•	

4.86	0.0590	0.17 Q				
4.96	0.0603	0.17 Q				
5.06	0.0617	0.17 Q	•			
5.15	0.0631	0.17 Q				
5.25	0.0645	0.17 Q				
5.35	0.0659	0.17 Q				
5.45	0.0673	0.17 Q				
5.55	0.0687	0.17 Q	•	•		
5.65	0.0702	0.17 Q				
5.75	0.0716	0.18 Q	•			•
5.85	0.0730	0.18 Q	•	•		
5.95	0.0745	0.18 Q				
6.05	0.0760	0.18 Q	•	•		
6.15	0.0774	0.18 Q	•	•		
6.25	0.0789	0.18 Q	•	•		
6.35	0.0804	0.18 Q	•			•
6.45	0.0819	0.18 Q	•	•		
6.55	0.0834	0.18 Q				
6.65	0.0849	0.19 Q	•			
6.75	0.0865	0.19 Q	•	•		
6.85	0.0880	0.19 Q	•	•		
6.95	0.0895	0.19 Q	•	•		
7.05	0.0911	0.19 Q				
7.14	0.0927	0.19 Q	•	•		
7.24	0.0943	0.19 Q	•	•		
7.34	0.0959	0.19 Q	•			
7.44	0.0975	0.20 Q	•	•		
7.54	0.0991	0.20 Q	•	•		
7.64	0.1007	0.20 Q	•	•		
7.74	0.1023	0.20 Q	•			•
7.84	0.1040	0.20 Q	•			•
7.94	0.1057	0.20 Q	•			
8.04	0.1073	0.20 Q	•			
8.14	0.1090	0.21 Q				
8.24	0.1107	0.21 Q	•			•
8.34	0.1125	0.21 Q	•			
8.44	0.1142	0.21 Q				
8.54	0.1159	0.21 Q	•	•	•	•
8.64	0.1177	0.21 Q				
8.74	0.1195	0.22 Q	•	•		
8.84	0.1213	0.22 Q	•	•	•	•
8.94	0.1231	0.22 Q	•	•	•	•
9.04	0.1249	0.22 Q	•	•	•	•
9.13	0.1267	0.22 Q	•			•

9.23	0.1286	0.23 Q					
9.33	0.1305	0.23 Q	•		•		
9.43	0.1323	0.23 Q	•				
9.53	0.1343	0.23 Q	•				
9.63	0.1362	0.23 Q	•	•		•	
9.73	0.1381	0.24 Q	•				
9.83	0.1401	0.24 Q				•	
9.93	0.1421	0.24 Q				•	
10.03	0.1441	0.24 Q	•				
10.13	0.1461	0.25 Q					
10.23	0.1481	0.25 Q	•				
10.33	0.1502	0.25 .Q	•				
10.43	0.1523	0.26 .Q					
10.53	0.1544	0.26 .Q					
10.63	0.1566	0.26 .Q					
10.73	0.1587	0.26 .Q					
10.83	0.1609	0.27 .Q					
10.93	0.1631	0.27 .Q					
11.02	0.1654	0.27 .Q					
11.12	0.1676	0.28 .Q					
11.22	0.1699	0.28 .Q					
11.32	0.1723	0.29 .Q					
11.42	0.1746	0.29 .Q					
11.52	0.1770	0.29 .Q					
11.62	0.1794	0.30 .Q					
11.72	0.1819	0.30 .Q					
11.82	0.1844	0.30 .Q					
11.92	0.1869	0.31 .Q					
12.02	0.1895	0.31 .Q					
12.12	0.1924	0.40 .Q					
12.22	0.1957	0.41 .Q					
12.32	0.1991	0.41 .Q					
12.42	0.2025	0.42 .Q					
12.52	0.2060	0.43 .Q					
12.62	0.2095	0.43 .Q					
12.72	0.2130	0.44 .Q					
12.82	0.2167	0.44 .Q					
12.92	0.2204	0.45 .Q					
13.02	0.2241	0.46 .Q					
13.11	0.2279	0.47 .Q					
13.21	0.2318	0.47 .Q					
13.31	0.2357	0.49 .Q					
13.41	0.2398	0.49 .Q	•				
13.51	0.2439	0.51 . Q					
		•					

13.61	0.2481	0.51 .	Q		•		
13.71	0.2524	0.53 .	Q				
13.81	0.2567	0.54 .	Q				
13.91	0.2612	0.55 .	Q				•
14.01	0.2658	0.56 .	Q				
14.11	0.2706	0.59 .	Q				•
14.21	0.2754	0.60 .	Q				
14.31	0.2804	0.62 .	Q	•	•		
14.41	0.2856	0.63 .	Q		•		
14.51	0.2909	0.66 .	Q				
14.61	0.2964	0.68 .	Q		•		
14.71	0.3021	0.71 .	Q		•		
14.81	0.3081	0.73 .	Q		•		
14.91	0.3143	0.77 .	Q		•		
15.01	0.3207	0.80 .	Q	•	•		
15.10	0.3275	0.85 .	Q				
15.20	0.3347	0.89 .	Q				
15.30	0.3423	0.97 .	Q		•		
15.40	0.3504	1.01 .	Q				
15.50	0.3587	1.00 .	Q				
15.60	0.3673	1.08 .	Q				
15.70	0.3771	1.30 .	Q				
15.80	0.3884	1.47 .	Q		•		
15.90	0.4030	2.08 .	Q		•		
16.00	0.4232	2.84 .		Q	•		
16.10	0.4704	8.62 .				Q	
16.20	0.5128	1.70 .	Q				
16.30	0.5247	1.18 .	Q		•		
16.40	0.5334	0.94 .	Q				
16.50	0.5410	0.93 .	Q		•		
16.60	0.5482	0.83 .	Q				
16.70	0.5547	0.75 .	Q		•		•
16.80	0.5606	0.69 .			•		•
16.90	0.5662	0.65 .	-		•		
17.00	0.5713	0.61 .	Q		•		
17.09	0.5762	0.57 .		•	•		•
17.19	0.5808	0.55 .	-		•		•
17.29	0.5852	0.52 .	-		•		
17.39	0.5894	0.50 .			•		•
17.49	0.5934	0.48 .			•		•
17.59	0.5973	0.46 .		•	•	•	•
17.69	0.6010	0.45 .		•	•	•	•
17.79	0.6047	0.43 .		•	•		•
17.89	0.6082	0.42 .	Q		•		

17.99	0.6116	0.41 .Q					
18.09	0.6147	0.34 .Q				•	
18.19	0.6173	0.31 .Q				•	
18.29	0.6198	0.30 .Q		•		•	
18.39	0.6223	0.29 .Q				•	
18.49	0.6246	0.28 .Q					
18.59	0.6269	0.28 .Q	•	•		٠	
18.69	0.6291	0.27 .Q				•	
18.79	0.6313	0.26 .Q	•	•		•	
18.89	0.6335	0.26 .Q					
18.98	0.6356	0.25 .Q	•	•		•	
19.08	0.6376	0.25 Q	•		•	•	
19.18	0.6396	0.24 Q			•		
19.28	0.6416	0.24 Q			•		
19.38	0.6435	0.23 Q					
19.48	0.6454	0.23 Q			•		
19.58	0.6472	0.22 Q					
19.68	0.6491	0.22 Q	•		•	•	
19.78	0.6509	0.22 Q	•		•	•	
19.88	0.6526	0.21 Q					
19.98	0.6544	0.21 Q					
20.08	0.6561	0.21 Q					
20.18	0.6577	0.20 Q					
20.28	0.6594	0.20 Q					
20.38	0.6610	0.20 Q					
20.48	0.6626	0.19 Q					
20.58	0.6642	0.19 Q					
20.68	0.6658	0.19 Q					
20.78	0.6673	0.19 Q					
20.88	0.6688	0.18 Q			•		
20.98	0.6703	0.18 Q	•		•	•	
21.07	0.6718	0.18 Q	•		•	•	
21.17	0.6733	0.18 Q	•		•		
21.27	0.6747	0.17 Q					
21.37	0.6761	0.17 Q					
21.47	0.6776	0.17 Q					
21.57	0.6789	0.17 Q			•		
21.67	0.6803	0.17 Q	•				
21.77	0.6817	0.16 Q	•				
21.87	0.6830	0.16 Q					
21.97	0.6844	0.16 Q					
22.07	0.6857	0.16 Q					
22.17	0.6870	0.16 Q					
22.27	0.6883	0.16 Q			•		
	2.200		-	-	-	-	

22.37	0.6896	0.15 Q			•	
22.47	0.6908	0.15 Q				
22.57	0.6921	0.15 Q				
22.67	0.6933	0.15 Q			•	
22.77	0.6946	0.15 Q				
22.87	0.6958	0.15 Q			•	
22.97	0.6970	0.15 Q			•	
23.06	0.6982	0.14 Q			•	
23.16	0.6994	0.14 Q			•	
23.26	0.7005	0.14 Q				
23.36	0.7017	0.14 Q	•		•	
23.46	0.7029	0.14 Q				
23.56	0.7040	0.14 Q				
23.66	0.7052	0.14 Q				
23.76	0.7063	0.14 Q				
23.86	0.7074	0.14 Q				
23.96	0.7085	0.13 Q				
24.06	0.7096	0.13 Q	•		•	
24.16	0.7102	0.00 Q				

TIME DURATION(minutes) OF PERCENTILES OF ESTIMATED PEAK FLOW RATE:

(Note: 100% of Peak Flow Rate estimate assumed to have an instantaneous time duration)

Percentile of Estimated	Duration				
Peak Flow Rate	(minutes)				
=======================================	====	=======			
0%	1444.7				
10%	83.6				
20%	17.9				
30%	11.9				
40%	6.0				
50%	6.0				
60%	6.0				
70%	6.0				
80%	6.0				
90%	6.0				

Eastern Subcatchment Existing System

********************************** RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE (Reference: 1986 ORANGE COUNTY HYDROLOGY CRITERION) (c) Copyright 1983-2014 Advanced Engineering Software (aes) Ver. 21.0 Release Date: 06/01/2014 License ID 1501 FILE NAME: C:\USERS\ENRIGHTP\DESKTOP\TEMP\XEAST.DAT TIME/DATE OF STUDY: 15:12 10/07/2016 ______ USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION: ______ --*TIME-OF-CONCENTRATION MODEL*--USER SPECIFIED STORM EVENT(YEAR) = 100.00 SPECIFIED MINIMUM PIPE SIZE(INCH) = 6.00 SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE = 0.90 *DATA BANK RAINFALL USED* *ANTECEDENT MOISTURE CONDITION (AMC) III ASSUMED FOR RATIONAL METHOD* *USER-DEFINED STREET-SECTIONS FOR COUPLED PIPEFLOW AND STREETFLOW MODEL* HALF- CROWN TO STREET-CROSSFALL: CURB GUTTER-GEOMETRIES: MANNING WIDTH CROSSFALL IN- / OUT-/PARK- HEIGHT WIDTH LIP HIKE FACTOR NO. (FT) (FT) SIDE / SIDE / WAY (FT) (FT) (FT) (FT) 1 30.0 20.0 0.018/0.018/0.020 0.67 2.00 0.0313 0.167 0.0150 GLOBAL STREET FLOW-DEPTH CONSTRAINTS: 1. Relative Flow-Depth = 0.00 FEET as (Maximum Allowable Street Flow Depth) - (Top-of-Curb) 2. (Depth)*(Velocity) Constraint = 6.0 (FT*FT/S) *SIZE PIPE WITH A FLOW CAPACITY GREATER THAN OR EQUAL TO THE UPSTREAM TRIBUTARY PIPE.* *USER-SPECIFIED MINIMUM TOPOGRAPHIC SLOPE ADJUSTMENT NOT SELECTED FLOW PROCESS FROM NODE 300.00 TO NODE 303.00 IS CODE = 21 >>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS< >>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<< _____ INITIAL SUBAREA FLOW-LENGTH(FEET) = 693.00

```
ELEVATION DATA: UPSTREAM(FEET) = 72.90 DOWNSTREAM(FEET) = 71.00
Tc = K^*[(LENGTH^{**} 3.00)/(ELEVATION CHANGE)]^{**}0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 31.441
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 2.157
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                     Ap SCS Tc
  LAND USE
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
AGRICULTURAL FAIR COVER
"PASTURE, DRYLAND"
                       0.99 0.40 1.000 69 31.44
                   Α
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 1.000
SUBAREA RUNOFF(CFS) = 1.56
TOTAL AREA(ACRES) = 0.99 PEAK FLOW RATE(CFS) = 1.56
*****************************
FLOW PROCESS FROM NODE 303.00 TO NODE 303.00 IS CODE = 1
>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<
______
TOTAL NUMBER OF STREAMS = 2
CONFLUENCE VALUES USED FOR INDEPENDENT STREAM 1 ARE:
TIME OF CONCENTRATION(MIN.) = 31.44
RAINFALL INTENSITY(INCH/HR) = 2.16
AREA-AVERAGED Fm(INCH/HR) = 0.40
AREA-AVERAGED Fp(INCH/HR) = 0.40
AREA-AVERAGED Ap = 1.00
EFFECTIVE STREAM AREA(ACRES) =
TOTAL STREAM AREA(ACRES) =
PEAK FLOW RATE(CFS) AT CONFLUENCE = 1.56
*************************
FLOW PROCESS FROM NODE 302.00 TO NODE 303.00 IS CODE = 21
_____
>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<
>>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<<
______
INITIAL SUBAREA FLOW-LENGTH(FEET) = 659.00
ELEVATION DATA: UPSTREAM(FEET) = 72.70 DOWNSTREAM(FEET) = 71.00
Tc = K^*[(LENGTH^{**} 3.00)/(ELEVATION CHANGE)]^{**}0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 31.192
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 2.167
```

SUBAREA Tc AND LOSS RATE DATA(AMC III):

DEVELOPMENT TYPE/ SCS SOIL AREA FP AP SCS TC LAND USE GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.) AGRICULTURAL FAIR COVER
"PASTURE,DRYLAND" A 1.71 0.40 1.000 69 31.19
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 1.000
SUBAREA RUNOFF(CFS) = 2.72
TOTAL AREA(ACRES) = 1.71 PEAK FLOW RATE(CFS) = 2.72

FLOW PROCESS FROM NODE 303.00 TO NODE 303.00 IS CODE = 1

>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<

TOTAL NUMBER OF STREAMS = 2

CONFLUENCE VALUES USED FOR INDEPENDENT STREAM 2 ARE:

TIME OF CONCENTRATION(MIN.) = 31.19

RAINFALL INTENSITY(INCH/HR) = 2.17

AREA-AVERAGED Fm(INCH/HR) = 0.40

AREA-AVERAGED Fp(INCH/HR) = 0.40

AREA-AVERAGED Ap = 1.00

EFFECTIVE STREAM AREA(ACRES) = 1.71

TOTAL STREAM AREA(ACRES) = 1.71

PEAK FLOW RATE(CFS) AT CONFLUENCE = 2.72

** CONFLUENCE DATA **

STREAM Q Tc Intensity Fp(Fm) Ap Ae HEADWATER NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE

- 1 1.56 31.44 2.157 0.40(0.40) 1.00 1.0 300.00
- 2 2.72 31.19 2.167 0.40(0.40) 1.00 1.7 302.00

RAINFALL INTENSITY AND TIME OF CONCENTRATION RATIO CONFLUENCE FORMULA USED FOR 2 STREAMS.

** PEAK FLOW RATE TABLE **

STREAM Q Tc Intensity Fp(Fm) Ap Ae HEADWATER NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE

- 1 4.28 31.19 2.167 0.40(0.40) 1.00 2.7 302.00
- 2 4.27 31.44 2.157 0.40(0.40) 1.00 2.7 300.00

COMPUTED CONFLUENCE ESTIMATES ARE AS FOLLOWS:

PEAK FLOW RATE(CFS) = 4.28 Tc(MIN.) = 31.19

EFFECTIVE AREA(ACRES) = 2.69 AREA-AVERAGED Fm(INCH/HR) = 0.40

AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 1.00TOTAL AREA(ACRES) = 2.7 LONGEST FLOWPATH FROM NODE 300.00 TO NODE 303.00 = 693.00 FEET. ************************ FLOW PROCESS FROM NODE 303.00 TO NODE 304.00 IS CODE = 41 ----->>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA< >>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)< ______ ELEVATION DATA: UPSTREAM(FEET) = 68.50 DOWNSTREAM(FEET) = 64.50 FLOW LENGTH(FEET) = 35.00 MANNING'S N = 0.013 DEPTH OF FLOW IN 24.0 INCH PIPE IS 4.0 INCHES PIPE-FLOW VELOCITY(FEET/SEC.) = 12.64 GIVEN PIPE DIAMETER(INCH) = 24.00 NUMBER OF PIPES = 1 PIPE-FLOW(CFS) = 4.28 PIPE TRAVEL TIME(MIN.) = 0.05 Tc(MIN.) = 31.24 LONGEST FLOWPATH FROM NODE 300.00 TO NODE 304.00 = 728.00 FEET. ______ **END OF STUDY SUMMARY:** TOTAL AREA(ACRES) = 2.7 TC(MIN.) = 31.24 EFFECTIVE AREA(ACRES) = 2.69 AREA-AVERAGED Fm(INCH/HR)= 0.40 AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 1.000 PEAK FLOW RATE(CFS) = 4.28** PEAK FLOW RATE TABLE ** Q Tc Intensity Fp(Fm) Ap Ae HEADWATER STREAM NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE 4.28 31.24 2.165 0.40(0.40) 1.00 2.7 302.00 1 4.27 31.49 2.156 0.40(0.40) 1.00 2.7 300.00 ______

END OF RATIONAL METHOD ANALYSIS

****	**********************
NO	N-HOMOGENEOUS WATERSHED AREA-AVERAGED LOSS RATE (Fm)
	AND LOW LOSS FRACTION ESTIMATIONS
(C) C	copyright 1989-2014 Advanced Engineering Software (aes)
Ve	er. 21.0 Release Date: 06/01/2014 License ID 1501
*****	**************************************
Problem	Descriptions:
	ainage Study
	Condition
West	
=======	:======================================
	-HOMOGENEOUS WATERSHED AREA-AVERAGED LOSS RATE (Fm)
AND LC	DW LOSS FRACTION ESTIMATIONS FOR AMC III:
TOTAL	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches)
SOIL-CO	OVER AREA PERCENT OF SCS CURVE LOSS RATE
TYPE	(Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD
1	0.99 100.00 49.(AMC II) 10.000 0.431
2	1.71 100.00 49.(AMC II) 10.000 0.431
TOTAL	AREA (Acres) = 2.70
Λ D ΕΛ_Λ	
ANLA-A	

	SMΔI	Ι ΔΡΕΔ	UNIT HY	/DRO	GRAPI	н МОГ	FI	
	=====			=====		=====		======================================
			Date: 0		_		-	

Problem D	escript	ions:						
SERC Drai	•							
Existing Co	onditio	ns						
East								
DATIONA				ON 6	25551	CIENT	4.72	
RATIONA							= 1./3	
TOTAL CA				-				
LOW LOS				- 3.3	990			
TIME OF			0.000	1)=3	1 2/1			
			•	•		FAK FI	∩W RΔ	TE FORMULA
ORANGE		-						
RETURN						.0 _ 5 / 1.	NE OSEI	
		-	NFALL V		(INCH	ES) = (0.52	
			INFALL \		-	-		
			IFALL VA		-	-		
			IFALL VA	•		•		
			IFALL VA					
			NFALL V	-		-		
				,		,		
TOTAL CA	ATCHM	1ENT R	UNOFF	VOLU	ME(A	CRE-FI	EET) =	0.94
TOTAL CA					-		-	0.33
*****	*****	*****	*****	****	****	*****	*****	*******
	OLUME		0. 2				10.0	
(HOURS)		(CFS)	J. Z	.5	5.0	1.5	10.0	
			 Դ					
0.38 0.0	0038	0.10	٠.	•		•		
		0.18 (•					
0.90 0.0	0114		ì .					

2.46	0.0353	0.19 Q					
2.98	0.0436	0.20 Q				•	
3.50	0.0521	0.20 Q				•	
4.02	0.0608	0.21 Q			•	•	
4.55	0.0698	0.21 Q				•	
5.07	0.0790	0.22 Q				•	
5.59	0.0885	0.22 Q		•		•	
6.11	0.0983	0.23 Q		•		•	
6.63	0.1084	0.24 Q				•	
7.15	0.1189	0.25 Q	•	•	•	•	
7.67	0.1297	0.25 .Q		•			
8.19	0.1409	0.27 .Q		•			
8.71	0.1526	0.28 .Q		•		•	
9.23	0.1648	0.29 .Q		•			
9.75	0.1775	0.30 .Q		•			
10.27	0.1910	0.32 .Q	•	•		•	
10.79	0.2051	0.33 .Q	•	•		•	
11.31	0.2201	0.36 .Q		•			
11.83	0.2360	0.38 .Q		•	•	•	
12.36	0.2544	0.48 .Q		•	•	•	
12.88	0.2766	0.55 . Q		•	•		
13.40	0.3018	0.62 . Q		•		•	
13.92	0.3293	0.66 . Q		•		•	
14.44	0.3604	0.78 . Q					
14.96	0.3960	0.87 . Q					
15.48	0.4405	1.20 . Q		•		•	
16.00	0.4970	1.43 . Q		•		•	
16.52	0.6196	4.28 .		Q.		•	
17.04	0.7331	1.00 . Q				•	
17.56	0.7699	0.71 . Q				•	
18.08	0.7978	0.58 . Q				•	
18.60	0.8189	0.40 .Q	•	•		•	
19.12	0.8350	0.35 .Q	•	•		•	
19.64	0.8491	0.31 .Q	•	•		•	
20.17	0.8619	0.28 .Q		•	•	•	
20.69	0.8736	0.26 .Q	•	•		•	
21.21	0.8845	0.24 Q	•	•	•	•	
21.73	0.8946	0.23 Q	•			•	
22.25	0.9041	0.21 Q	•	•	•	•	
22.77	0.9130	0.20 Q					
23.29	0.9216	0.19 Q	•	•		•	
23.81	0.9297	0.18 Q	•	•			
24.33	0.9375	0.18 Q	•	•		•	
24.85	0.9413	0.00 Q	•	•	•	•	

TIME DURATION(minutes) OF PERCENTILES OF ESTIMATED PEAK FLOW RATE:

(Note: 100% of Peak Flow Rate estimate assumed to have an instantaneous time duration)

Percentile of Estimated	Dura	tion			
Peak Flow Rate	(minutes)				
=======================================	====	======			
0%	1468.3				
10%	374.9				
20%	156.2				
30%	62.5				
40%	31.2				
50%	31.2				
60%	31.2				
70%	31.2				
80%	31.2				
90%	31.2				

Dale Avenue Subcatchment Existing System

************************** RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE (Reference: 1986 ORANGE COUNTY HYDROLOGY CRITERION) (c) Copyright 1983-2014 Advanced Engineering Software (aes) Ver. 21.0 Release Date: 06/01/2014 License ID 1501 FILE NAME: C:\USERS\ENRIGHTP\DESKTOP\TEMP\XDALE.DAT TIME/DATE OF STUDY: 15:16 10/07/2016 ______ USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION: ______ --*TIME-OF-CONCENTRATION MODEL*--USER SPECIFIED STORM EVENT(YEAR) = 100.00 SPECIFIED MINIMUM PIPE SIZE(INCH) = 6.00 SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE = 0.90 *DATA BANK RAINFALL USED* *ANTECEDENT MOISTURE CONDITION (AMC) III ASSUMED FOR RATIONAL METHOD* *USER-DEFINED STREET-SECTIONS FOR COUPLED PIPEFLOW AND STREETFLOW MODEL* HALF- CROWN TO STREET-CROSSFALL: CURB GUTTER-GEOMETRIES: MANNING WIDTH CROSSFALL IN- / OUT-/PARK- HEIGHT WIDTH LIP HIKE FACTOR NO. (FT) (FT) SIDE / SIDE / WAY (FT) (FT) (FT) (FT) 1 30.0 20.0 0.018/0.018/0.020 0.67 2.00 0.0313 0.167 0.0150 GLOBAL STREET FLOW-DEPTH CONSTRAINTS: 1. Relative Flow-Depth = 0.00 FEET as (Maximum Allowable Street Flow Depth) - (Top-of-Curb) 2. (Depth)*(Velocity) Constraint = 6.0 (FT*FT/S) *SIZE PIPE WITH A FLOW CAPACITY GREATER THAN OR EQUAL TO THE UPSTREAM TRIBUTARY PIPE.* *USER-SPECIFIED MINIMUM TOPOGRAPHIC SLOPE ADJUSTMENT NOT SELECTED FLOW PROCESS FROM NODE 400.00 TO NODE 401.00 IS CODE = 21 >>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS< >>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<< _____ INITIAL SUBAREA FLOW-LENGTH(FEET) = 19.00

```
ELEVATION DATA: UPSTREAM(FEET) = 73.70 DOWNSTREAM(FEET) = 72.20
```

Tc = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]**0.20SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 5.000 * 100 YEAR RAINFALL INTENSITY(INCH/HR) = 6.187 SUBAREA Tc AND LOSS RATE DATA(AMC III): DEVELOPMENT TYPE/ SCS SOIL AREA Fp Ap SCS Tc LAND USE GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.) AGRICULTURAL FAIR COVER "PASTURE, DRYLAND" Α 0.05 0.40 1.000 69 5.00 SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40 SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 1.000 SUBAREA RUNOFF(CFS) = 0.27 TOTAL AREA(ACRES) = 0.05 PEAK FLOW RATE(CFS) = 0.27

END OF STUDY SUMMARY:

TOTAL AREA(ACRES) = 0.1 TC(MIN.) = 5.00EFFECTIVE AREA(ACRES) = 0.05 AREA-AVERAGED Fm(INCH/HR) = 0.40AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 1.000PEAK FLOW RATE(CFS) = 0.27

END OF RATIONAL METHOD ANALYSIS

*****	******************************
NO	ON-HOMOGENEOUS WATERSHED AREA-AVERAGED LOSS RATE (Fm)
	AND LOW LOSS FRACTION ESTIMATIONS
 (C)	Copyright 1989-2014 Advanced Engineering Software (aes)
V	/er. 21.0 Release Date: 06/01/2014 License ID 1501
******	**************************
Problen	n Descriptions:
	rainage Study
Existing	g Condition
Dale	
	N-HOMOGENEOUS WATERSHED AREA-AVERAGED LOSS RATE (Fm)
AND L	OW LOSS FRACTION ESTIMATIONS FOR AMC III:
TOTAL	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches)
SOIL-C	COVER AREA PERCENT OF SCS CURVE LOSS RATE
TYPE	(Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD
1	0.05 100.00 49.(AMC II) 10.000 0.431
TOTAL	AREA (Acres) = 0.05
	 AVERAGED LOSS RATE, Fm (in./hr.) = 10.000
AREA-	

Problem Descriptions: SERC Drainage Study Existing Condition Dale

```
RATIONAL METHOD CALIBRATION COEFFICIENT = 1.93

TOTAL CATCHMENT AREA(ACRES) = 0.05

SOIL-LOSS RATE, Fm,(INCH/HR) = 9.990

LOW LOSS FRACTION = 0.569

TIME OF CONCENTRATION(MIN.) = 5.00

SMALL AREA PEAK Q COMPUTED USING PEAK FLOW RATE FORMULA

ORANGE COUNTY "VALLEY" RAINFALL VALUES ARE USED

RETURN FREQUENCY(YEARS) = 100

5-MINUTE POINT RAINFALL VALUE(INCHES) = 0.52

30-MINUTE POINT RAINFALL VALUE(INCHES) = 1.09

1-HOUR POINT RAINFALL VALUE(INCHES) = 1.45

3-HOUR POINT RAINFALL VALUE(INCHES) = 2.43

6-HOUR POINT RAINFALL VALUE(INCHES) = 3.36

24-HOUR POINT RAINFALL VALUE(INCHES) = 5.63
```

.....

TOTAL CATCHMENT RUNOFF VOLUME(ACRE-FEET) = 0.02 TOTAL CATCHMENT SOIL-LOSS VOLUME(ACRE-FEET) = 0.00

TIME	VOLUME	Q	0.	2.5	5	.0	7.5	10.0
(HOURS) (AF)	(CFS)						
0.08	0.0000	0.00	Q					
0.17	0.0000	0.00	Q					
0.25	0.0001	0.00	Q					
0.33	0.0001	0.00	Q					
0.42	0.0001	0.00	Q					
0.50	0.0001	0.00	Q					
0.58	0.0002	0.00	Q					
0.67	0.0002	0.00	Q					
0.75	0.0002	0.00	Q					
0.83	0.0003	0.00	Q					
0.92	0.0003	0.00	Q					
1.00	0.0003	0.00	Q					
1.08	0.0003	0.00	Q					

1.17	0.0004	0.00	Q			
1.25	0.0004	0.00	Q			
1.33	0.0004	0.00	Q			
1.42	0.0004	0.00	Q	•		
1.50	0.0005	0.00	Q			
1.58	0.0005	0.00	Q			
1.67	0.0005	0.00	Q			
1.75	0.0006	0.00	Q			
1.83	0.0006	0.00	Q			
1.92	0.0006	0.00	Q		•	
2.00	0.0006	0.00	Q			
2.08	0.0007	0.00	Q			
2.17	0.0007	0.00	Q		•	
2.25	0.0007	0.00	Q			
2.33	0.0007	0.00	Q			
2.42	0.0008	0.00	Q			
2.50	0.0008	0.00	Q			•
2.58	0.0008	0.00	Q			•
2.67	0.0009	0.00	Q			
2.75	0.0009	0.00	Q			•
2.83	0.0009	0.00	Q			•
2.92	0.0010	0.00	Q			•
3.00	0.0010	0.00	Q			•
3.08	0.0010	0.00	Q			
3.17	0.0010	0.00	Q			
3.25	0.0011	0.00	Q			
3.33	0.0011	0.00	Q			•
3.42	0.0011	0.00	Q			
3.50	0.0012	0.00	Q			
3.58	0.0012	0.00	Q			
3.67	0.0012	0.00	Q			
3.75	0.0013	0.00	Q			
3.83	0.0013	0.00	Q			
3.92	0.0013	0.00	Q		•	
4.00	0.0013	0.00	Q			
4.08	0.0014	0.00	Q		•	
4.17	0.0014	0.00	Q			
4.25	0.0014	0.00	Q			
4.33	0.0015	0.00	Q		•	
4.42	0.0015	0.00	Q			
4.50	0.0015	0.00	Q			
4.58	0.0016	0.00	Q			
4.67	0.0016	0.00	Q			
4.75	0.0016	0.00	Q			

4.83	0.0017	0.00 Q				
4.92	0.0017	0.00 Q				
5.00	0.0017	0.00 Q				
5.08	0.0018	0.00 Q				•
5.17	0.0018	0.00 Q	•		•	•
5.25	0.0018	0.00 Q	•		•	•
5.33	0.0019	0.00 Q		•		
5.42	0.0019	0.00 Q				•
5.50	0.0019	0.00 Q				•
5.58	0.0020	0.00 Q				
5.67	0.0020	0.00 Q				
5.75	0.0020	0.00 Q				
5.83	0.0021	0.00 Q	•	•	•	•
5.92	0.0021	0.01 Q				
6.00	0.0021	0.01 Q				
6.08	0.0022	0.01 Q	•	•	•	•
6.17	0.0022	0.01 Q		•		
6.25	0.0022	0.01 Q	•	•	•	•
6.33	0.0023	0.01 Q	•	•		•
6.42	0.0023	0.01 Q	•	•	•	•
6.50	0.0023	0.01 Q	•	•	•	•
6.58	0.0024	0.01 Q	•	•	•	•
6.67	0.0024	0.01 Q	•	•	•	•
6.75	0.0025	0.01 Q	•		•	•
6.83	0.0025	0.01 Q	•	•	•	•
6.92	0.0025	0.01 Q	•	•	•	•
7.00	0.0026	0.01 Q	•	•	•	•
7.08	0.0026	0.01 Q	٠	•	٠	•
7.17	0.0026	0.01 Q	٠	•	٠	•
7.25	0.0027	0.01 Q	٠	•	٠	•
7.33	0.0027	0.01 Q	•	•	•	•
7.42	0.0028	0.01 Q	•	•	•	•
7.50	0.0028	0.01 Q	•	•	•	•
7.58	0.0028	0.01 Q	•	•	•	•
7.67	0.0029	0.01 Q	•	•	•	•
7.75	0.0029	0.01 Q	•	•	•	•
7.83	0.0029	0.01 Q	•	•	•	•
7.92	0.0030	0.01 Q	•	•	•	•
8.00	0.0030	0.01 Q	•	•	•	•
8.08	0.0031	0.01 Q	•	•	•	•
8.17	0.0031	0.01 Q	•	•	•	•
8.25	0.0031	0.01 Q	•	•	•	•
8.33	0.0032	0.01 Q	•	•	•	•
8.42	0.0032	0.01 Q	•	•	•	•

8.50	0.0033	0.01 Q				
8.58	0.0033	0.01 Q	•			
8.67	0.0034	0.01 Q				
8.75	0.0034	0.01 Q			•	
8.83	0.0034	0.01 Q	•			
8.92	0.0035	0.01 Q	•			
9.00	0.0035	0.01 Q	•			
9.08	0.0036	0.01 Q		•	•	
9.17	0.0036	0.01 Q	•			
9.25	0.0037	0.01 Q	•			
9.33	0.0037	0.01 Q	•			
9.42	0.0037	0.01 Q	•			
9.50	0.0038	0.01 Q	•			
9.58	0.0038	0.01 Q	•			
9.67	0.0039	0.01 Q		•		
9.75	0.0039	0.01 Q	•			
9.83	0.0040	0.01 Q	•			
9.92	0.0040	0.01 Q	•			
10.00	0.0041	0.01 Q	•	•		•
10.08	0.0041	0.01 Q		•		
10.17	0.0042	0.01 Q	•	•		•
10.25	0.0042	0.01 Q		•		
10.33	0.0043	0.01 Q		•		
10.42	0.0043	0.01 Q		•		
10.50	0.0044	0.01 Q		•		
10.58	0.0044	0.01 Q	•	•		•
10.67	0.0045	0.01 Q	•	•		•
10.75	0.0045	0.01 Q	•	•	•	
10.83	0.0046	0.01 Q	•	•		•
10.92	0.0046	0.01 Q	•	•	•	
11.00	0.0047	0.01 Q	•	•	•	
11.08	0.0047	0.01 Q	•			•
11.17	0.0048	0.01 Q	•			•
11.25	0.0048	0.01 Q	•			
11.33	0.0049	0.01 Q	•			
11.42	0.0050	0.01 Q				•
11.50	0.0050	0.01 Q	•			
11.58	0.0051	0.01 Q	•		•	
11.67	0.0051	0.01 Q	•			
11.75	0.0052	0.01 Q	•		•	
11.83	0.0052	0.01 Q	•	•	•	•
11.92	0.0053	0.01 Q	•	•	•	•
12.00	0.0054	0.01 Q		•		•
12.08	0.0054	0.01 Q	•			

12.17	0.0055	0.01	Q				
12.25	0.0056	0.01	Q				
12.33	0.0057	0.01	-				
12.42	0.0058	0.01					
12.50	0.0058	0.01	Q				
12.58	0.0059	0.01	Q	•			
12.67	0.0060	0.01	-				
12.75	0.0061	0.01	Q	•			•
12.83	0.0062	0.01	-	•			•
12.92	0.0063	0.01		•			•
13.00	0.0064	0.01	Q	•			•
13.08	0.0064	0.01	-	•			•
13.17	0.0065	0.01	Q	•			•
13.25	0.0066	0.01	Q	•			•
13.33	0.0067	0.01	-	•			•
13.42	0.0068	0.01	-	•			•
13.50	0.0069	0.01	Q		•		•
13.58	0.0070	0.01	-	•			•
13.67	0.0071	0.01		•			•
13.75	0.0072	0.02		•			•
13.83	0.0073	0.02		•	•		
13.92	0.0074	0.02		•	•		
14.00	0.0075	0.02	-	•	•		
14.08	0.0077	0.02					
14.17	0.0078	0.02		•	•		
14.25	0.0079	0.02		•	•		
14.33	0.0080	0.02		•	•		
14.42	0.0081	0.02					
14.50	0.0083	0.02		•	•		
14.58	0.0084	0.02	-				
14.67	0.0085	0.02	Q				
14.75	0.0087	0.02		•	•	•	•
14.83	0.0088	0.02	-	•	•	•	•
14.92	0.0090	0.02		•	•	•	•
15.00	0.0091	0.02	-	•	•	•	
15.08	0.0093	0.02		•	•	•	
15.17	0.0094	0.02		•	•	•	•
15.25	0.0096	0.03	-				
15.33	0.0098	0.03				•	
15.42	0.0100	0.03				•	
15.50	0.0102	0.03		•	•		
15.58	0.0104	0.03		•			
15.67	0.0106	0.03		•			
15.75	0.0109	0.04	Q	•	•	•	•

15.83	0.0112	0.05	Q				
15.92	0.0116	0.07	Q				
16.00	0.0121	0.09	Q	•			
16.08	0.0133	0.27	.Q	•	•	•	
16.17	0.0144	0.05	Q	•			
16.25	0.0147	0.04	Q	•			
16.33	0.0150	0.03	Q	•			
16.42	0.0152	0.03	Q	•			
16.50	0.0154	0.03	Q	•			
16.58	0.0155	0.02	Q	•			
16.67	0.0157	0.02	Q	•			
16.75	0.0158	0.02	Q	•			
16.83	0.0160	0.02	Q	•			
16.92	0.0161	0.02	Q	•			
17.00	0.0162	0.02	Q	•			
17.08	0.0163	0.02	Q	•			
17.17	0.0164	0.02	Q	•			
17.25	0.0165	0.01	Q	•			
17.33	0.0166	0.01	Q				
17.42	0.0167	0.01	Q				
17.50	0.0168	0.01	Q				
17.58	0.0169	0.01	Q				
17.67	0.0170	0.01	Q	•			
17.75	0.0171	0.01	Q				
17.83	0.0172	0.01	Q				
17.92	0.0173	0.01	Q				
18.00	0.0174	0.01	Q				
18.08	0.0174	0.01	-	•			
18.17	0.0175	0.01	•	•			
18.25	0.0175	0.01	Q	•			
18.33	0.0176	0.01	Q	•			
18.42	0.0177	0.01		•	•		
18.50	0.0177	0.01		•	•		•
18.58	0.0178	0.01	Q			•	
18.67	0.0178	0.01	-	•			
18.75	0.0179	0.01	-	•			
18.83	0.0179	0.01	-	•	•		•
18.92	0.0180	0.01		•			
19.00	0.0180	0.01	-	•			•
19.08	0.0181	0.01	-	•			•
19.17	0.0181	0.01		•	•	•	•
19.25	0.0182	0.01		•			•
19.33	0.0182	0.01	-	•			•
19.42	0.0183	0.01	Q	•	•	•	

19.50	0.0183	0.01 Q				
19.58	0.0184	0.01 Q	•	•		
19.67	0.0184	0.01 Q		•		
19.75	0.0184	0.01 Q				
19.83	0.0185	0.01 Q	•	•		
19.92	0.0185	0.01 Q				
20.00	0.0186	0.01 Q	•	•		
20.08	0.0186	0.01 Q				
20.17	0.0186	0.01 Q		•		
20.25	0.0187	0.01 Q		•		
20.33	0.0187	0.01 Q				
20.42	0.0188	0.01 Q		•		
20.50	0.0188	0.01 Q	•	•	•	
20.58	0.0188	0.01 Q		•		
20.67	0.0189	0.01 Q				
20.75	0.0189	0.01 Q		•		
20.83	0.0189	0.01 Q	•	•		
20.92	0.0190	0.01 Q		•		
21.00	0.0190	0.01 Q		•		
21.08	0.0190	0.01 Q		٠		
21.17	0.0191	0.01 Q		٠		
21.25	0.0191	0.00 Q		•		
21.33	0.0192	0.00 Q				
21.42	0.0192	0.00 Q		•		
21.50	0.0192	0.00 Q		•		
21.58	0.0193	0.00 Q		•		
21.67	0.0193	0.00 Q				
21.75	0.0193	0.00 Q		•		
21.83	0.0193	0.00 Q		•		
21.92	0.0194	0.00 Q				
22.00	0.0194	0.00 Q				
22.08	0.0194	0.00 Q		•		
22.17	0.0195	0.00 Q				
22.25	0.0195	0.00 Q				
22.33	0.0195	0.00 Q		•		
22.42	0.0196	0.00 Q		•		
22.50	0.0196	0.00 Q				
22.58	0.0196	0.00 Q		•		
22.67	0.0197	0.00 Q		•		
22.75	0.0197	0.00 Q				
22.83	0.0197	0.00 Q		•		
22.92	0.0197	0.00 Q				
23.00	0.0198	0.00 Q				
23.08	0.0198	0.00 Q				

23.17	0.0198	0.00 Q			
23.25	0.0199	0.00 Q			
23.33	0.0199	0.00 Q			
23.42	0.0199	0.00 Q			
23.50	0.0199	0.00 Q			
23.58	0.0200	0.00 Q			
23.67	0.0200	0.00 Q			
23.75	0.0200	0.00 Q			
23.83	0.0200	0.00 Q			
23.92	0.0201	0.00 Q			
24.00	0.0201	0.00 Q			
24.08	0.0201	0.00 Q			

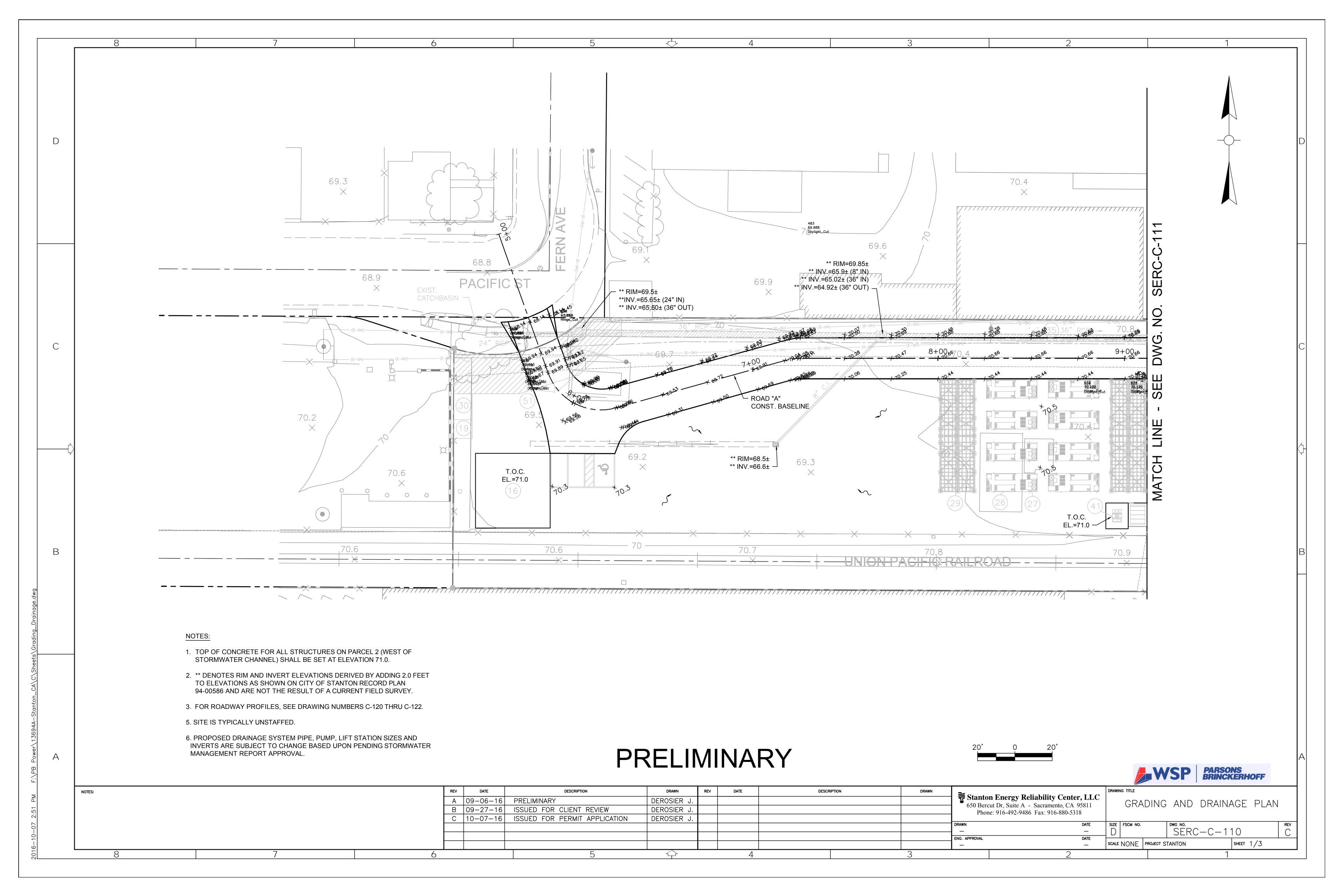
TIME DURATION(minutes) OF PERCENTILES OF ESTIMATED PEAK FLOW RATE:

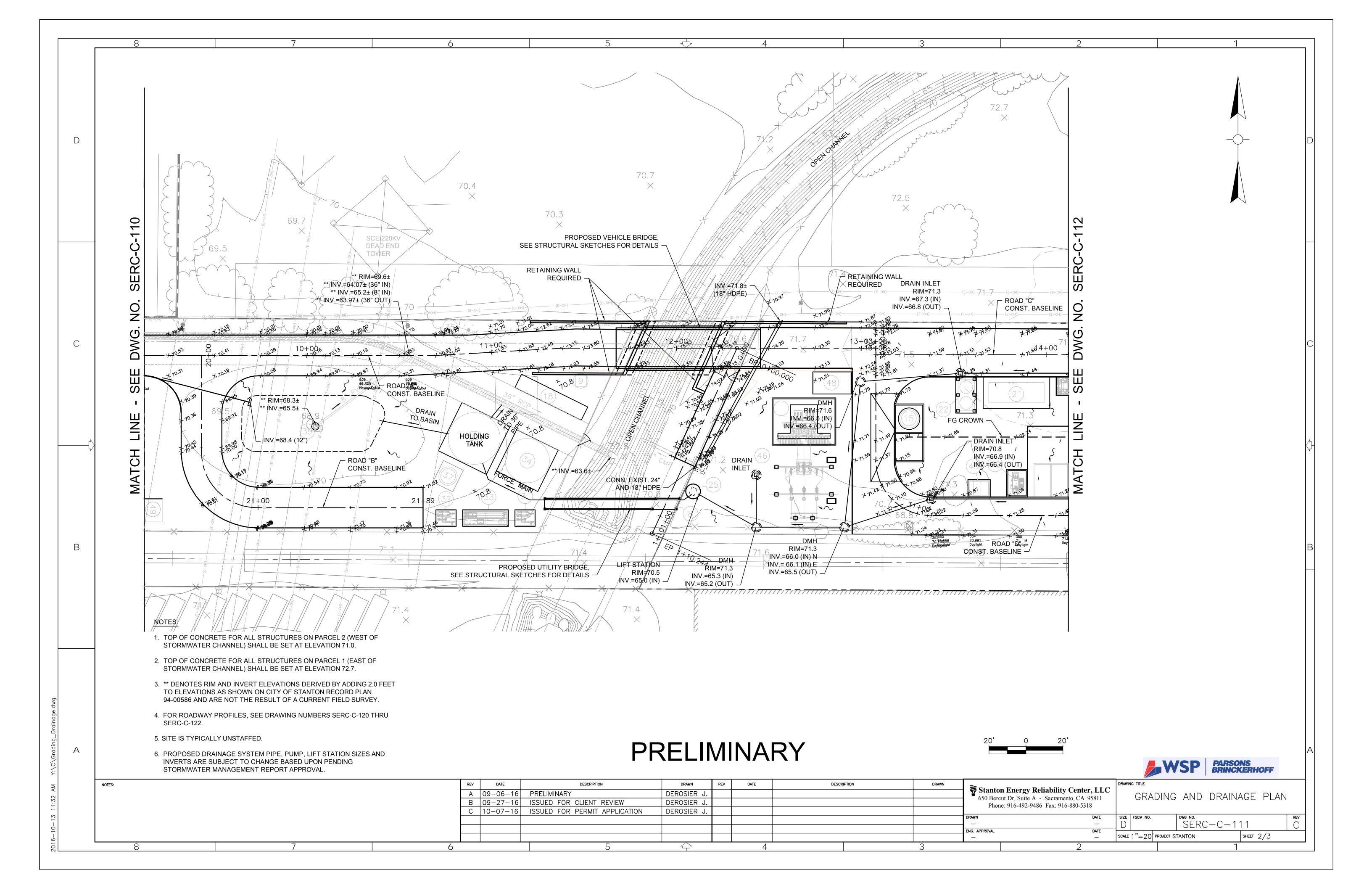
(Note: 100% of Peak Flow Rate estimate assumed to have an instantaneous time duration)

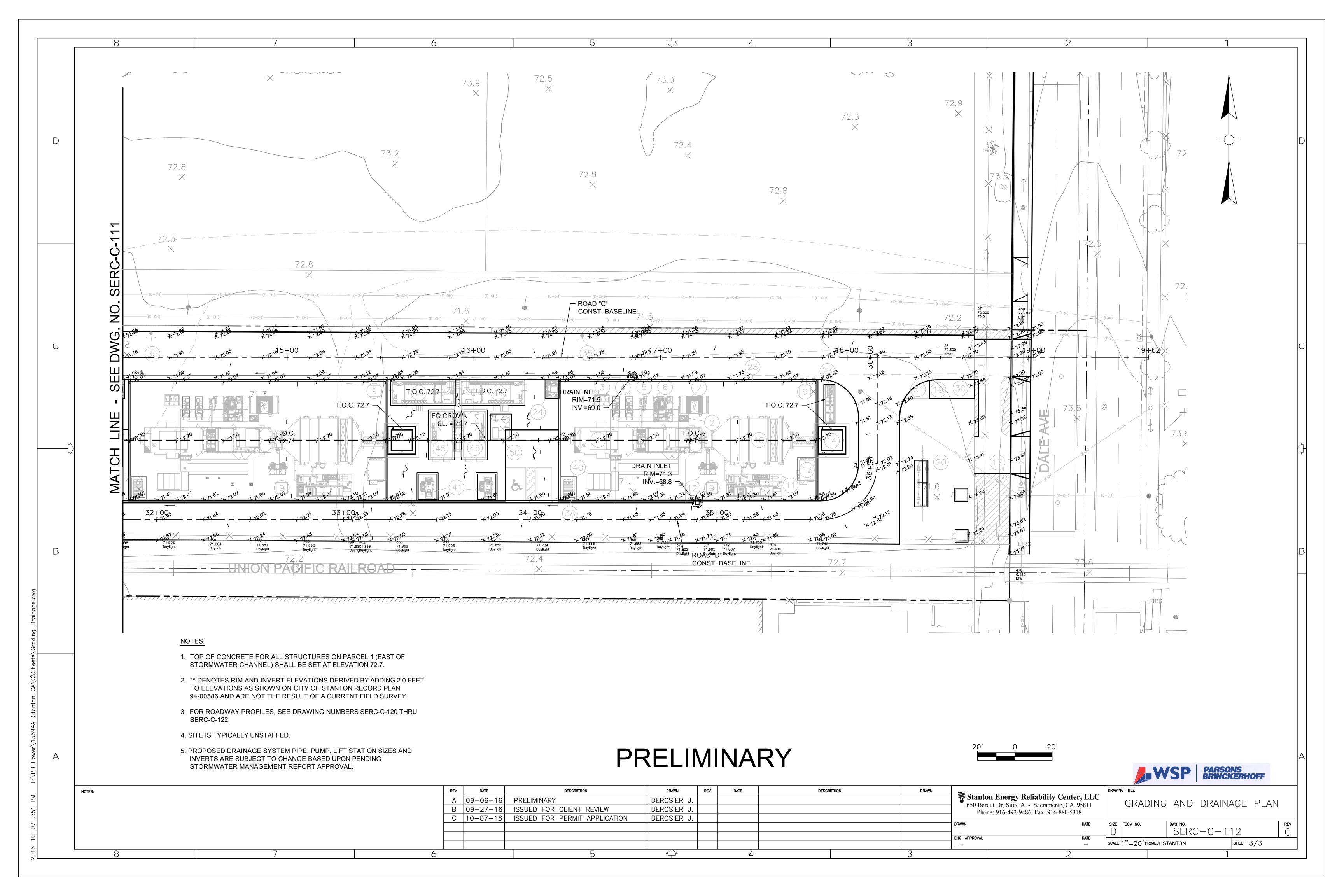
Percentile of Estimated		uration
Peak Flow Rate	(mir	nutes)
=======================================	===	=======
0%	1440.0	
10%	65.0	
20%	15.0	
30%	10.0	
40%	5.0	
50%	5.0	
60%	5.0	
70%	5.0	
80%	5.0	
90%	5.0	

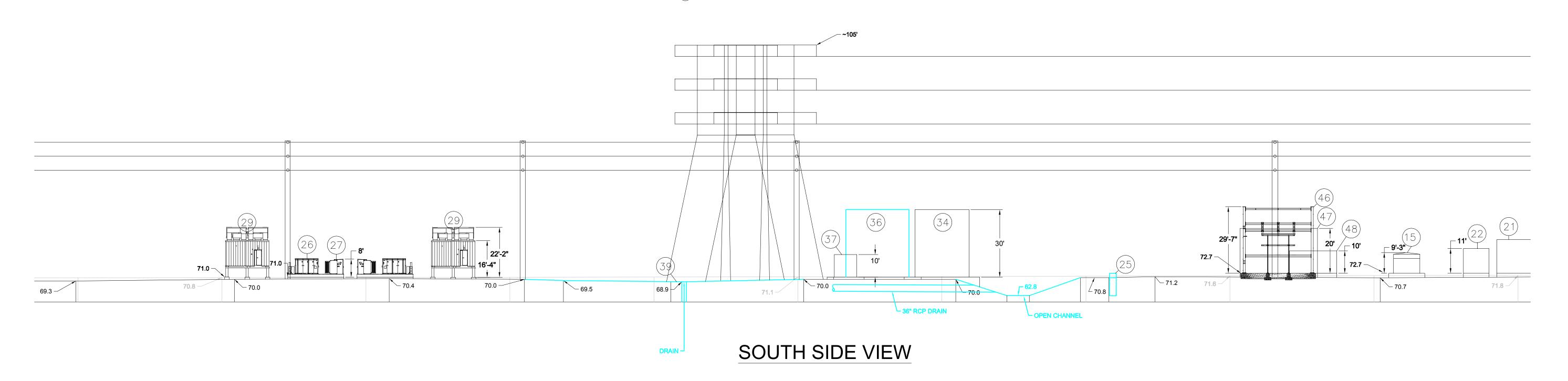


APPENDIX G

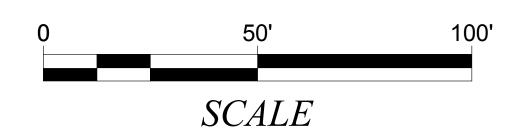








(51) FIRE ALARM ANNUNCIATOR PANEL



PRELIMINARY

OTE:

THIS DRAWING REPRESENTS THE COMPONENTS OF THE CONCEPTUAL DRAINAGE DESIGN.
THE ELEMENTS FOR THE FACILITY ARE APPROXIMATE AND ARE BEING SHOWN FOR REFERENCE ONLY.



APPENDIX H

Western Subcatchment (Direct to Channel) Proposed System

RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE

(Reference: 1986 ORANGE COUNTY HYDROLOGY CRITERION)

(c) Copyright 1983-2014 Advanced Engineering Software (aes)

Ver. 21.0 Release Date: 06/01/2014 License ID 1501

FILE NAME: C:\AES\PWESTD.DAT

TIME/DATE OF STUDY: 13:12 10/13/2016

USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION:

--*TIME-OF-CONCENTRATION MODEL*--

USER SPECIFIED STORM EVENT(YEAR) = 100.00

SPECIFIED MINIMUM PIPE SIZE(INCH) = 6.00

SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE = 0.90

DATA BANK RAINFALL USED

ANTECEDENT MOISTURE CONDITION (AMC) III ASSUMED FOR RATIONAL METHOD

USER-DEFINED STREET-SECTIONS FOR COUPLED PIPEFLOW AND STREETFLOW MODEL
HALF- CROWN TO STREET-CROSSFALL: CURB GUTTER-GEOMETRIES: MANNING
WIDTH CROSSFALL IN- / OUT-/PARK- HEIGHT WIDTH LIP HIKE FACTOR

NO. (FT) (FT) SIDE / SIDE / WAY (FT) (FT) (FT) (FT) (n)

1 30.0 20.0 0.018/0.018/0.020 0.67 2.00 0.0313 0.167 0.0150

GLOBAL STREET FLOW-DEPTH CONSTRAINTS:

- 1. Relative Flow-Depth = 0.00 FEET as (Maximum Allowable Street Flow Depth) (Top-of-Curb)
- 2. (Depth)*(Velocity) Constraint = 6.0 (FT*FT/S)
- *SIZE PIPE WITH A FLOW CAPACITY GREATER THAN

OR EQUAL TO THE UPSTREAM TRIBUTARY PIPE.*

*USER-SPECIFIED MINIMUM TOPOGRAPHIC SLOPE ADJUSTMENT NOT SELECTED

FLOW PROCESS FROM NODE 100.00 TO NODE 101.00 IS CODE = 21

>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<

>>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<<

```
INITIAL SUBAREA FLOW-LENGTH(FEET) = 216.00
ELEVATION DATA: UPSTREAM(FEET) = 69.10 DOWNSTREAM(FEET) = 68.70
Tc = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]**0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 9.186
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 4.367
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                      Ap SCS Tc
  LAND USE
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
COMMERCIAL
                      0.43  0.40  0.100  52  9.19
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.100
SUBAREA RUNOFF(CFS) = 1.67
TOTAL AREA(ACRES) = 0.43 PEAK FLOW RATE(CFS) = 1.67
FLOW PROCESS FROM NODE 101.00 TO NODE 102.00 IS CODE = 41
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<
______
ELEVATION DATA: UPSTREAM(FEET) = 66.20 DOWNSTREAM(FEET) = 65.65
FLOW LENGTH(FEET) = 62.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 24.0 INCH PIPE IS 4.7 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 3.90
GIVEN PIPE DIAMETER(INCH) = 24.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
                1.67
PIPE TRAVEL TIME(MIN.) = 0.27 Tc(MIN.) = 9.45
LONGEST FLOWPATH FROM NODE 100.00 TO NODE 102.00 = 278.00 FEET.
**************************
FLOW PROCESS FROM NODE 102.00 TO NODE 202.00 IS CODE = 41
  -----
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<
______
ELEVATION DATA: UPSTREAM(FEET) = 65.50 DOWNSTREAM(FEET) = 65.02
FLOW LENGTH(FEET) = 163.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 36.0 INCH PIPE IS 5.4 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 2.51
GIVEN PIPE DIAMETER(INCH) = 36.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
                1.67
PIPE TRAVEL TIME(MIN.) = 1.08 Tc(MIN.) = 10.53
```

```
LONGEST FLOWPATH FROM NODE 100.00 TO NODE 202.00 = 441.00 FEET.
******************************
FLOW PROCESS FROM NODE 202.00 TO NODE 202.00 IS CODE = 1
>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE <<< <
______
TOTAL NUMBER OF STREAMS = 2
CONFLUENCE VALUES USED FOR INDEPENDENT STREAM 1 ARE:
TIME OF CONCENTRATION(MIN.) = 10.53
RAINFALL INTENSITY(INCH/HR) = 4.04
AREA-AVERAGED Fm(INCH/HR) = 0.04
AREA-AVERAGED Fp(INCH/HR) = 0.40
AREA-AVERAGED Ap = 0.10
EFFECTIVE STREAM AREA(ACRES) = 0.43
TOTAL STREAM AREA(ACRES) =
PEAK FLOW RATE(CFS) AT CONFLUENCE =
                               1.67
***************************
FLOW PROCESS FROM NODE 200.00 TO NODE 201.00 IS CODE = 21
>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<
>>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<<
______
INITIAL SUBAREA FLOW-LENGTH(FEET) = 195.00
ELEVATION DATA: UPSTREAM(FEET) = 69.90 DOWNSTREAM(FEET) = 68.50
Tc = K^*[(LENGTH^{**} 3.00)/(ELEVATION CHANGE)]^{**}0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 6.725
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 5.221
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                    Ap SCS Tc
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
  LAND USE
COMMERCIAL
                     0.42  0.40  0.100  52  6.72
AGRICULTURAL FAIR COVER
"PASTURE, DRYLAND"
                       0.35 0.40 1.000 69 15.62
URBAN GOOD COVER
"TURF"
                  0.03 0.40 1.000 53 15.62
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.527
SUBAREA RUNOFF(CFS) = 3.64
TOTAL AREA(ACRES) = 0.81 PEAK FLOW RATE(CFS) = 3.64
***************************
```

FLOW PROCESS FROM NODE 201.00 TO NODE 202.00 IS CODE = 41

>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA

>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)

ELEVATION DATA: UPSTREAM(FEET) = 66.60 DOWNSTREAM(FEET) = 65.90

FLOW LENGTH(FEET) = 81.00 MANNING'S N = 0.013

ASSUME FULL-FLOWING PIPELINE

PIPE-FLOW VELOCITY(FEET/SEC.) = 3.05

(PIPE FLOW VELOCITY CORRESPONDING TO FULL PIPE CAPACITY FLOW)

GIVEN PIPE DIAMETER(INCH) = 8.00 NUMBER OF PIPES = 1

PIPE-FLOW(CFS) = 3.64

PIPE TRAVEL TIME(MIN.) = 0.44 Tc(MIN.) = 7.17

LONGEST FLOWPATH FROM NODE 200.00 TO NODE 202.00 = 276.00 FEET.

FLOW PROCESS FROM NODE 202.00 TO NODE 202.00 IS CODE = 1

>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<

TOTAL NUMBER OF STREAMS = 2

CONFLUENCE VALUES USED FOR INDEPENDENT STREAM 2 ARE:

TIME OF CONCENTRATION(MIN.) = 7.17

RAINFALL INTENSITY(INCH/HR) = 5.03

AREA-AVERAGED Fm(INCH/HR) = 0.21

AREA-AVERAGED Fp(INCH/HR) = 0.40

AREA-AVERAGED Ap = 0.53

EFFECTIVE STREAM AREA(ACRES) = 0.81

TOTAL STREAM AREA(ACRES) = 0.81

PEAK FLOW RATE(CFS) AT CONFLUENCE = 3.64

** CONFLUENCE DATA **

STREAM Q Tc Intensity Fp(Fm) Ap Ae HEADWATER NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE

- 1 1.67 10.53 4.037 0.40(0.04) 0.10 0.4 100.00
- 2 3.64 7.17 5.034 0.40(0.21) 0.53 0.8 200.00

RAINFALL INTENSITY AND TIME OF CONCENTRATION RATIO CONFLUENCE FORMULA USED FOR 2 STREAMS.

** PEAK FLOW RATE TABLE **

STREAM Q Tc Intensity Fp(Fm) Ap Ae HEADWATER NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE

```
5.06 7.17 5.034 0.40(0.17) 0.41 1.1 200.00
  2
      4.56 10.53 4.037 0.40(0.15) 0.38 1.2 100.00
COMPUTED CONFLUENCE ESTIMATES ARE AS FOLLOWS:
PEAK FLOW RATE(CFS) = 5.06 Tc(MIN.) = 7.17
EFFECTIVE AREA(ACRES) = 1.10 AREA-AVERAGED Fm(INCH/HR) = 0.17
AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.41
TOTAL AREA(ACRES) =
                  1.2
LONGEST FLOWPATH FROM NODE 100.00 TO NODE 202.00 = 441.00 FEET.
FLOW PROCESS FROM NODE 202.00 TO NODE 205.00 IS CODE = 41
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<
_____
ELEVATION DATA: UPSTREAM(FEET) = 64.92 DOWNSTREAM(FEET) = 64.07
FLOW LENGTH(FEET) = 288.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 36.0 INCH PIPE IS 9.3 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 3.48
GIVEN PIPE DIAMETER(INCH) = 36.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
               5.06
PIPE TRAVEL TIME(MIN.) = 1.38 Tc(MIN.) = 8.55
LONGEST FLOWPATH FROM NODE 100.00 TO NODE 205.00 = 729.00 FEET.
************************************
FLOW PROCESS FROM NODE 205.00 TO NODE 206.00 IS CODE = 41
-----
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<
______
ELEVATION DATA: UPSTREAM(FEET) = 63.97 DOWNSTREAM(FEET) = 63.60
FLOW LENGTH(FEET) = 124.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 36.0 INCH PIPE IS 9.3 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 3.49
GIVEN PIPE DIAMETER(INCH) = 36.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
               5.06
PIPE TRAVEL TIME(MIN.) = 0.59 Tc(MIN.) = 9.14
LONGEST FLOWPATH FROM NODE 100.00 TO NODE 206.00 = 853.00 FEET.
______
END OF STUDY SUMMARY:
TOTAL AREA(ACRES) = 1.2 TC(MIN.) = 9.14
```

EFFECTIVE AREA(ACRES) = 1.10 AREA-AVERAGED Fm(INCH/HR)= 0.17 AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.413

PEAK FLOW RATE(CFS) = 5.06

** PEAK FLOW RATE TABLE **

STREAM Q Tc Intensity Fp(Fm) Ap Ae HEADWATER NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE

- 1 5.06 9.14 4.380 0.40(0.17) 0.41 1.1 200.00
- 2 4.56 12.56 3.649 0.40(0.15) 0.38 1.2 100.00

END OF RATIONAL METHOD ANALYSIS

			FRACTION ESTIMATIONS
(C) Ce Ve	opyright r. 21.0 I	: 1989-201 Release Da	14 Advanced Engineering Software (aes) ate: 06/01/2014 License ID 1501 ***********************************
Problem I SERC Dra Proposed West Dir	inage St d Condit	udy	
AND LO	W LOSS	FRACTION	WATERSHED AREA-AVERAGED LOSS RATE (Fm) N ESTIMATIONS FOR AMC III: ON RAINFALL DEPTH = 5.63 (inches)
SOIL-CC			ERCENT OF SCS CURVE LOSS RATE
TYPE	(Acres	s) PERVIC	DUS AREA NUMBER Fp(in./hr.) YIELD
TYPE 1	(Acres 0.43	s) PERVIC 2.00	OUS AREA NUMBER Fp(in./hr.) YIELD 98.(AMC II) 10.000 0.958
TYPE 1 2	(Acres 0.43 0.09	2.00 2.00	OUS AREA NUMBER Fp(in./hr.) YIELD 98.(AMC II) 10.000 0.958 98.(AMC II) 10.000 0.958
TYPE 1 2 3	(Acres 0.43 0.09 0.15	2.00 2.00 2.00 100.00	OUS AREA NUMBER Fp(in./hr.) YIELD 98.(AMC II) 10.000 0.958 98.(AMC II) 10.000 0.958 76.(AMC II) 10.000 0.836
TYPE 1 2	(Acres 0.43 0.09	2.00 2.00	OUS AREA NUMBER Fp(in./hr.) YIELD 98.(AMC II) 10.000 0.958 98.(AMC II) 10.000 0.958

RATIONAL METHOD CALIBRATION COEFFICIENT = 1.10

TOTAL CATCHMENT AREA(ACRES) = 1.24

SOIL-LOSS RATE, Fm,(INCH/HR) = 5.868

LOW LOSS FRACTION = 0.153

TIME OF CONCENTRATION(MIN.) = 9.14

SMALL AREA PEAK Q COMPUTED USING PEAK FLOW RATE FORMULA

ORANGE COUNTY "VALLEY" RAINFALL VALUES ARE USED

RETURN FREQUENCY(YEARS) = 100

5-MINUTE POINT RAINFALL VALUE(INCHES) = 0.52

30-MINUTE POINT RAINFALL VALUE(INCHES) = 1.09

1-HOUR POINT RAINFALL VALUE(INCHES) = 1.45

3-HOUR POINT RAINFALL VALUE(INCHES) = 2.43

6-HOUR POINT RAINFALL VALUE(INCHES) = 3.36

24-HOUR POINT RAINFALL VALUE(INCHES) = 5.63

.....

TOTAL CATCHMENT RUNOFF VOLUME(ACRE-FEET) = 0.54 TOTAL CATCHMENT SOIL-LOSS VOLUME(ACRE-FEET) = 0.04

	VOLUME 5) (AF)	(CFS)			5.	0	7.5	10.0
0.00	0.0000							
0.16	0.0006	0.10	Q					
0.31	0.0019	0.10	Q	•				
0.46	0.0032	0.10	Q	•				
0.61	0.0045	0.10	Q	•				
0.77	0.0058	0.10	Q	•				
0.92	0.0071	0.10	Q	•				
1.07	0.0084	0.10	Q			•		
1.22	0.0097	0.11	Q	•				
1.38	0.0111	0.11	Q	•				
1.53	0.0124	0.11	Q	•				
1.68	0.0138	0.11	Q	•				
1.83	0.0151	0.11	Q	•				
1.99	0.0165	0.11	Q	•				
2.14	0.0179	0.11	Q	•				
2.29	0.0192	0.11	Q					
2.44	0.0206	0.11	Q					

2.59	0.0220	0.11 Q				
2.75	0.0235	0.11 Q	•			
2.90	0.0249	0.11 Q	•	•	•	•
3.05	0.0263	0.11 Q	•	•		
3.20	0.0278	0.12 Q			•	
3.36	0.0292	0.12 Q			•	
3.51	0.0307	0.12 Q	•	•		
3.66	0.0322	0.12 Q	•	•		
3.81	0.0337	0.12 Q	•	•		
3.97	0.0352	0.12 Q		•		•
4.12	0.0367	0.12 Q	•	•		
4.27	0.0382	0.12 Q	•	•		
4.42	0.0398	0.12 Q	•	•		
4.57	0.0413	0.12 Q	•	•		
4.73	0.0429	0.12 Q	•	•		
4.88	0.0444	0.13 Q	•		•	
5.03	0.0460	0.13 Q	•			
5.18	0.0476	0.13 Q	•			
5.34	0.0493	0.13 Q	•			
5.49	0.0509	0.13 Q	•	•		
5.64	0.0525	0.13 Q	•	•		
5.79	0.0542	0.13 Q	•			
5.95	0.0559	0.13 Q	•	•		
6.10	0.0576	0.14 Q		•		
6.25	0.0593	0.14 Q		•		
6.40	0.0610	0.14 Q	•	•		
6.56	0.0628	0.14 Q	•	•		
6.71	0.0645	0.14 Q	•	•		
6.86	0.0663	0.14 Q	•			
7.01	0.0681	0.14 Q			•	
7.16	0.0699	0.14 Q	•	•		
7.32	0.0718	0.15 Q			•	
7.47	0.0736	0.15 Q			•	
7.62	0.0755	0.15 Q	•			
7.77	0.0774	0.15 Q	•			
7.93	0.0793	0.15 Q				
8.08	0.0813	0.15 Q	•			
8.23	0.0832	0.16 Q	•			
8.38	0.0852	0.16 Q	•			
8.54	0.0872	0.16 Q	•			
8.69	0.0893	0.16 Q	•			
8.84	0.0913	0.17 Q	•			
8.99	0.0934	0.17 Q				
9.15	0.0956	0.17 Q	•			

9.30	0.0977	0.17 Q			
9.45	0.0999	0.18 Q			-
9.60	0.1021	0.18 Q			
9.75	0.1044	0.18 Q			
9.91	0.1066	0.18 Q			
10.06	0.1090	0.19 Q			
10.21	0.1113	0.19 Q			
10.36	0.1137	0.19 Q			
10.52	0.1161	0.19 Q			
10.67	0.1186	0.20 Q			
10.82	0.1211	0.20 Q			
10.97	0.1237	0.21 Q			
11.13	0.1263	0.21 Q			
11.28	0.1290	0.21 Q			
11.43	0.1317	0.22 Q			
11.58	0.1344	0.22 Q			
11.73	0.1373	0.23 Q			
11.89	0.1402	0.23 Q			
12.04	0.1431	0.24 Q			
12.19	0.1465	0.31 .Q			
12.34	0.1504	0.31 .Q			
12.50	0.1544	0.32 .Q			
12.65	0.1584	0.32 .Q			
12.80	0.1626	0.33 .Q			
12.95	0.1668	0.34 .Q			
13.11	0.1712	0.35 .Q			
13.26	0.1757	0.36 .Q			
13.41	0.1803	0.37 .Q			
13.56	0.1850	0.38 .Q			
13.72	0.1900	0.40 .Q			
13.87	0.1950	0.41 .Q			
14.02	0.2003	0.43 .Q			
14.17	0.2058	0.44 .Q			
14.32	0.2115	0.47 .Q			
14.48	0.2175	0.48 .Q		•	
14.63	0.2238	0.52 . Q			
14.78	0.2304	0.54 . Q			
14.93	0.2375	0.58 . Q			
15.09	0.2450	0.61 .Q			
15.24	0.2532	0.69 . Q			
15.39	0.2621	0.73 . Q	•		
15.54	0.2716	0.77 . Q	•		
15.70	0.2818	0.86 . Q	•		
15.85	0.2950	1.23 . Q			

16.00	0.3133	1.68 . Q .		
16.15	0.3557	5.06	Q	
16.30	0.3938	1.00 . Q .		
16.46	0.4048	0.74 . Q .		
16.61	0.4135	0.65 . Q .		
16.76	0.4211	0.56 . Q .		
16.91	0.4278	0.50 .Q .		
17.07	0.4338	0.45 .Q .		•
17.22	0.4392	0.42 .Q .		•
17.37	0.4443	0.39 .Q .		
17.52	0.4491	0.37 .Q .		
17.68	0.4536	0.35 .Q .		
17.83	0.4578	0.33 .Q .		
17.98	0.4619	0.31 .Q .		
18.13	0.4655	0.26 .Q .		
18.28	0.4686	0.23 Q .		
18.44	0.4715	0.22 Q .		
18.59	0.4742	0.21 Q .		
18.74	0.4768	0.20 Q .		
18.89	0.4793	0.20 Q .		
19.05	0.4817	0.19 Q .		
19.20	0.4841	0.18 Q .		
19.35	0.4864	0.18 Q .		
19.50	0.4886	0.17 Q .		
19.66	0.4907	0.17 Q .		
19.81	0.4928	0.16 Q .		
19.96	0.4949	0.16 Q .		
20.11	0.4969	0.16 Q .		
20.27	0.4988	0.15 Q .		
20.42	0.5007	0.15 Q .		
20.57	0.5026	0.15 Q .		
20.72	0.5044	0.14 Q .	•	•
20.87	0.5062	0.14 Q .		
21.03	0.5079	0.14 Q .		
21.18	0.5096	0.13 Q .		
21.33	0.5113	0.13 Q .		
21.48	0.5130	0.13 Q .		
21.64	0.5146	0.13 Q .		
21.79	0.5162	0.13 Q .		
21.94	0.5177	0.12 Q .	•	
22.09	0.5193	0.12 Q .		
22.25	0.5208	0.12 Q .		•
22.40	0.5223	0.12 Q .	•	
22.55	0.5237	0.12 Q .		

22.70	0.5252	0.11 Q			
22.86	0.5266	0.11 Q			
23.01	0.5280	0.11 Q			
23.16	0.5294	0.11 Q			
23.31	0.5308	0.11 Q			
23.46	0.5321	0.11 Q			
23.62	0.5335	0.11 Q			
23.77	0.5348	0.10 Q			
23.92	0.5361	0.10 Q			
24.07	0.5374	0.10 Q			
24.23	0.5380	0.00 Q			

TIME DURATION(minutes) OF PERCENTILES OF ESTIMATED PEAK FLOW RATE:

(Note: 100% of Peak Flow Rate estimate assumed to have an instantaneous time duration)

Percentile of Estimated	Dur	ration
Peak Flow Rate	(minut	tes)
=======================================	====	=======
0%	1444.1	
10%	137.1	
20%	27.4	
30%	18.3	
40%	9.1	
50%	9.1	
60%	9.1	
70%	9.1	
80%	9.1	
90%	9.1	

Western Subcatchment (Detention Basin) Proposed System

RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE

(Reference: 1986 ORANGE COUNTY HYDROLOGY CRITERION)

(c) Copyright 1983-2014 Advanced Engineering Software (aes)

Ver. 21.0 Release Date: 06/01/2014 License ID 1501

FILE NAME: C:\AES\PWESTB.DAT

TIME/DATE OF STUDY: 13:33 10/13/2016

USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION:

--*TIME-OF-CONCENTRATION MODEL*--

USER SPECIFIED STORM EVENT(YEAR) = 100.00 SPECIFIED MINIMUM PIPE SIZE(INCH) = 6.00

SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE = 0.90

DATA BANK RAINFALL USED

ANTECEDENT MOISTURE CONDITION (AMC) III ASSUMED FOR RATIONAL METHOD

USER-DEFINED STREET-SECTIONS FOR COUPLED PIPEFLOW AND STREETFLOW MODEL
HALF- CROWN TO STREET-CROSSFALL: CURB GUTTER-GEOMETRIES: MANNING
WIDTH CROSSFALL IN- / OUT-/PARK- HEIGHT WIDTH LIP HIKE FACTOR

NO. (FT) (FT) SIDE / SIDE / WAY (FT) (FT) (FT) (FT) (n)

1 30.0 20.0 0.018/0.018/0.020 0.67 2.00 0.0313 0.167 0.0150

GLOBAL STREET FLOW-DEPTH CONSTRAINTS:

- 1. Relative Flow-Depth = 0.00 FEET
 - as (Maximum Allowable Street Flow Depth) (Top-of-Curb)
- 2. (Depth)*(Velocity) Constraint = 6.0 (FT*FT/S)
- *SIZE PIPE WITH A FLOW CAPACITY GREATER THAN

OR EQUAL TO THE UPSTREAM TRIBUTARY PIPE.*

*USER-SPECIFIED MINIMUM TOPOGRAPHIC SLOPE ADJUSTMENT NOT SELECTED

FLOW PROCESS FROM NODE 203.00 TO NODE 204.00 IS CODE = 21

>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<

>>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<<

```
INITIAL SUBAREA FLOW-LENGTH(FEET) = 205.00
ELEVATION DATA: UPSTREAM(FEET) = 75.33 DOWNSTREAM(FEET) = 68.30
Tc = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]**0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 5.018
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 6.175
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                    Ap SCS Tc
  LAND USE
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
COMMERCIAL
                     0.51 0.40 0.100 52 5.02
AGRICULTURAL FAIR COVER
"PASTURE,DRYLAND"
                       Α
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.420
SUBAREA RUNOFF(CFS) = 4.30
TOTAL AREA(ACRES) = 0.80 PEAK FLOW RATE(CFS) = 4.30
*****************************
FLOW PROCESS FROM NODE 204.00 TO NODE 205.00 IS CODE = 41
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<
______
ELEVATION DATA: UPSTREAM(FEET) = 65.50 DOWNSTREAM(FEET) = 65.20
FLOW LENGTH(FEET) = 63.00 MANNING'S N = 0.013
ASSUME FULL-FLOWING PIPELINE
PIPE-FLOW VELOCITY(FEET/SEC.) = 2.26
(PIPE FLOW VELOCITY CORRESPONDING TO FULL PIPE CAPACITY FLOW)
GIVEN PIPE DIAMETER(INCH) = 8.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
               4.30
PIPE TRAVEL TIME(MIN.) = 0.46 Tc(MIN.) = 5.48
LONGEST FLOWPATH FROM NODE 203.00 TO NODE 205.00 = 268.00 FEET.
*******************************
FLOW PROCESS FROM NODE 205.00 TO NODE 206.00 IS CODE = 41
_____
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<
______
ELEVATION DATA: UPSTREAM(FEET) = 63.97 DOWNSTREAM(FEET) = 63.60
FLOW LENGTH(FEET) = 124.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 36.0 INCH PIPE IS 8.6 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 3.33
```

END OF STUDY SUMMARY:

TOTAL AREA(ACRES) = 0.8 TC(MIN.) = 6.10EFFECTIVE AREA(ACRES) = 0.80 AREA-AVERAGED Fm(INCH/HR) = 0.17AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.420PEAK FLOW RATE(CFS) = 4.30

END OF RATIONAL METHOD ANALYSIS

NO	N-HOMOGENEOUS WATERSHED AREA-AVERAGED LOSS RATE (Fm) AND LOW LOSS FRACTION ESTIMATIONS
	:=====================================
	er. 21.0 Release Date: 06/01/2014 License ID 1501 ***********************************
Problem	Descriptions:
SERC Dra	ainage Study
•	d Condition
West Ba	sin
	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches)
	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) OVER AREA PERCENT OF SCS CURVE LOSS RATE
TOTAL SOIL-CO	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) OVER AREA PERCENT OF SCS CURVE LOSS RATE (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD
TOTAL SOIL-CO TYPE 1	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) OVER AREA PERCENT OF SCS CURVE LOSS RATE (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD 0.10 100.00 76.(AMC II) 10.000 0.836
TOTAL SOIL-CO	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) OVER AREA PERCENT OF SCS CURVE LOSS RATE (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD
TOTAL SOIL-CO TYPE 1 2 3 TOTAL	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) OVER AREA PERCENT OF SCS CURVE LOSS RATE (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD 0.10 100.00 76.(AMC II) 10.000 0.836 0.44 100.00 72.(AMC II) 10.000 0.778 0.25 2.00 98.(AMC II) 10.000 0.958 AREA (Acres) = 0.79
TOTAL SOIL-CO TYPE 1 2 3 TOTAL	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) OVER AREA PERCENT OF SCS CURVE LOSS RATE (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD 0.10 100.00 76.(AMC II) 10.000 0.836 0.44 100.00 72.(AMC II) 10.000 0.778 0.25 2.00 98.(AMC II) 10.000 0.958

	SMA	LL AREA	A UNI	T HYDI	ROGRAP	н мог	DEL	
•) Copyrigh Ver. 21.0	Release	e Date	e: 06/0	1/2014	Licens	ng Softv se ID 15	
Proble	m Descrip	tions:						
SERC I	Drainage S	study						
Propo	sed Condi	tion						
West	Basin 							
	ONAL MET					_	= 1.16	
	AL CATCHN		-	-)		
	LOSS RAT		-	•	6.964			
	OF CONC		•	-	- 610			
			-	-		ΕΔΚ ΕΙ	ΟW/ RΔ	TE FORMULA
	NGE COUN	-						
_	JRN FREQU					202071	002.	_
	AINUTE PC	-		-		IES) = (0.52	
	MINUTE P				-	-		
1-H	IOUR POI	NT RAII	NFALI	L VALU	E(INCH	S) = 1.	.45	
3-H	IOUR POI	NT RAII	NFALI	L VALU	E(INCH	S) = 2.	.43	
6-H	IOUR POI	NT RAII	NFALI	L VALU	E(INCH	ES) = 3.	.36	
24-l	HOUR PO	INT RA	INFAL	L VAL	JE(INCH	ES) = 5	5.63	
TOTA	AL CATCHN	ΛENT Ι	RUNC	FF VC	LUME(A	ACRE-FI	EET) =	0.36
TOTA	AL CATCHN	ΛENT S	OIL-LO	oss vo	DLUME(A	ACRE-FI	EET) =	0.01
*****								*********
TIME	VOLUM		0.	2.5	5.0	7.5	10.0	
(HOUR	S) (AF)	(CFS)						
,								
	0.0001	0.07	Q					
		0.07 0.07	•			•		
0.04			Q		 			

0.45	0.0024	0.07 Q		•	•	
0.55	0.0030	0.07 Q		•		
0.65	0.0036	0.07 Q		•		
0.75	0.0041	0.07 Q				
0.85	0.0047	0.07 Q				
0.95	0.0053	0.07 Q				
1.06	0.0059	0.07 Q				
1.16	0.0065	0.07 Q		•		
1.26	0.0071	0.07 Q				
1.36	0.0077	0.07 Q		•		
1.46	0.0083	0.07 Q				
1.56	0.0089	0.07 Q				
1.67	0.0095	0.07 Q				
1.77	0.0101	0.07 Q				
1.87	0.0107	0.07 Q				
1.97	0.0113	0.07 Q				
2.07	0.0119	0.07 Q				
2.17	0.0126	0.07 Q	•			
2.28	0.0132	0.07 Q	•			
2.38	0.0138	0.07 Q	•			
2.48	0.0144	0.07 Q				
2.58	0.0151	0.08 Q				
2.68	0.0157	0.08 Q	•			
2.78	0.0163	0.08 Q				
2.88	0.0170	0.08 Q		•		
2.99	0.0176	0.08 Q		•		
3.09	0.0183	0.08 Q	•			
3.19	0.0189	0.08 Q				
3.29	0.0196	0.08 Q				
3.39	0.0202	0.08 Q				
3.50	0.0209	0.08 Q	•			
3.60	0.0216	0.08 Q				
3.70	0.0222	0.08 Q				
3.80	0.0229	0.08 Q		•		
3.90	0.0236	0.08 Q				
4.00	0.0242	0.08 Q				
4.11	0.0249	0.08 Q		•		
4.21	0.0256	0.08 Q	•			
4.31	0.0263	0.08 Q		•		
4.41	0.0270	0.08 Q		•		
4.51	0.0277	0.08 Q				
4.61	0.0284	0.08 Q				
4.72	0.0291	0.08 Q			•	
4.82	0.0298	0.08 Q			•	

4.92	0.0305	0.08 Q				
5.02	0.0312	0.09 Q				
5.12	0.0319	0.09 Q	•			
5.22	0.0327	0.09 Q	•	•		
5.32	0.0334	0.09 Q	•	•		
5.43	0.0341	0.09 Q	•	•		
5.53	0.0348	0.09 Q	•	•		
5.63	0.0356	0.09 Q	•	•		
5.73	0.0363	0.09 Q	•	•		
5.83	0.0371	0.09 Q	•	•	•	•
5.93	0.0378	0.09 Q	•	•	•	•
6.04	0.0386	0.09 Q		•		
6.14	0.0394	0.09 Q	•	•	•	•
6.24	0.0401	0.09 Q	•	•	•	•
6.34	0.0409	0.09 Q		•		
6.44	0.0417	0.09 Q	•	•		
6.55	0.0425	0.09 Q	•			
6.65	0.0433	0.09 Q				
6.75	0.0441	0.10 Q				
6.85	0.0449	0.10 Q				
6.95	0.0457	0.10 Q				
7.05	0.0465	0.10 Q	•	•		
7.16	0.0473	0.10 Q				
7.26	0.0481	0.10 Q	•	•		
7.36	0.0489	0.10 Q	•	•		
7.46	0.0498	0.10 Q	•	•		
7.56	0.0506	0.10 Q				
7.66	0.0515	0.10 Q				
7.76	0.0523	0.10 Q				
7.87	0.0532	0.10 Q				
7.97	0.0540	0.10 Q				
8.07	0.0549	0.10 Q				
8.17	0.0558	0.11 Q				
8.27	0.0567	0.11 Q				
8.38	0.0576	0.11 Q				
8.48	0.0585	0.11 Q				
8.58	0.0594	0.11 Q				
8.68	0.0603	0.11 Q				
8.78	0.0612	0.11 Q				
8.88	0.0622	0.11 Q				
8.99	0.0631	0.11 Q				
9.09	0.0641	0.11 Q				
9.19	0.0650	0.11 Q				
9.29	0.0660	0.12 Q	•			

9.39	0.0670	0.12 Q	•	•	•	•	
9.49	0.0680	0.12 Q	•	•	•	•	
9.60	0.0690	0.12 Q	•	•	•	•	
9.70	0.0700	0.12 Q	•	•	•	•	
9.80	0.0710	0.12 Q	•	•	•		
9.90	0.0720	0.12 Q	•	•	•	•	
10.00	0.0731	0.12 Q	•	•	•		
10.10	0.0741	0.13 Q	•	•	•		
10.20	0.0752	0.13 Q	•	•	•		
10.31	0.0762	0.13 Q	•	•	•		
10.41	0.0773	0.13 Q	•	•	•		
10.51	0.0784	0.13 Q	•		•		
10.61	0.0795	0.13 Q					
10.71	0.0806	0.13 Q					
10.82	0.0818	0.14 Q	•		•		
10.92	0.0829	0.14 Q	•		•		
11.02	0.0841	0.14 Q	•		•		
11.12	0.0853	0.14 Q			•		
11.22	0.0865	0.14 Q			•		
11.32	0.0877	0.14 Q					
11.43	0.0889	0.15 Q					
11.53	0.0901	0.15 Q					
11.63	0.0914	0.15 Q					
11.73	0.0927	0.15 Q					
11.83	0.0940	0.16 Q					
11.93	0.0953	0.16 Q					
12.03	0.0966	0.16 Q					
12.14	0.0982	0.20 Q					
12.24	0.0999	0.21 Q					
12.34	0.1016	0.21 Q		-			
12.44	0.1034	0.21 Q					
12.54	0.1052	0.22 Q	•	•	•		
12.65	0.1071	0.22 Q	•	•	•	•	
12.75	0.1089	0.22 Q	•	•	•	•	
12.85	0.1108	0.22 Q 0.23 Q	•	•	•	•	
12.95	0.1127	0.23 Q	•	•	•	•	
13.05	0.1127	0.23 Q 0.24 Q	•	•	•	•	
13.15	0.1147	0.24 Q 0.24 Q	•	•	•	•	
			•	•	•	•	
13.26	0.1187	0.24 Q	•	•	•	•	
13.36	0.1208	0.25 Q	•	•	•	•	
13.46	0.1229	0.25 .Q	•	•	•	•	
13.56	0.1251	0.26 .Q	•	•	•	•	
13.66	0.1273	0.27 .Q	•	•	•	•	
13.76	0.1295	0.27 .Q	•	•	•	•	

13.87	0.1318	0.28	.Q					
13.97	0.1342	0.28	.Q					
14.07	0.1366	0.29	.Q					
14.17	0.1391	0.30					•	
14.27	0.1417	0.31	.Q					
14.37	0.1443	0.32					•	
14.48	0.1471	0.33						
14.58	0.1499	0.34	.Q					
14.68	0.1528	0.36						
14.78	0.1559	0.37	.Q		•		•	
14.88	0.1591	0.39						
14.98	0.1624	0.40						
15.09	0.1659	0.43	.Q		•		•	
15.19	0.1696	0.45	.Q					
15.29	0.1735	0.49						
15.39	0.1777	0.51	-		•	•	•	
15.49	0.1819	0.50						
15.59	0.1863	0.54	-					
15.70	0.1913	0.65			•	•	•	
15.80	0.1972	0.74	-		•	•	•	
15.90	0.2047	1.04			•	•		
16.00	0.2150	1.43	-		•	•	•	
16.10	0.2391	4.30			Q.	•	•	
16.20	0.2608	0.85			•		•	
16.31	0.2669	0.59			•	•	•	
16.41	0.2714	0.48	-		•	•	•	
16.51	0.2753	0.47			•	•	•	
16.61	0.2790	0.42			•		•	
16.71	0.2824	0.38	-		•		•	
16.81	0.2854	0.35			•		•	
16.92	0.2883	0.33			•		•	
17.02	0.2909	0.31		•	•	•	•	
17.12	0.2934	0.29		•	•	•	•	
17.22	0.2958	0.27		•	•	•	•	
17.32	0.2980	0.26	-		•	•	•	
17.42	0.3002	0.25		•	•	•	•	
17.52	0.3023	0.24			•	•	•	
17.63	0.3043	0.23	-		•	•	•	
17.73	0.3062	0.23		•	•	•	•	
17.83	0.3080	0.22			•	•		
17.93	0.3098	0.21		•	•	•	•	
18.03	0.3116	0.21		•	•	•	•	
18.14	0.3131	0.16		•	•	•		
18.24	0.3144	0.15	Q	•	•	•	•	

18.34	0.3157	0.15 Q		
18.44	0.3170	0.15 Q		
18.54	0.3182	0.14 Q		
18.64	0.3194	0.14 Q		
18.74	0.3205	0.14 Q		
18.85	0.3216	0.13 Q		
18.95	0.3227	0.13 Q		
19.05	0.3238	0.13 Q		
19.15	0.3248	0.12 Q		
19.25	0.3259	0.12 Q		
19.36	0.3269	0.12 Q		
19.46	0.3279	0.12 Q		
19.56	0.3288	0.11 Q		
19.66	0.3298	0.11 Q		
19.76	0.3307	0.11 Q		
19.86	0.3316	0.11 Q		
19.97	0.3325	0.11 Q		
20.07	0.3334	0.10 Q		
20.17	0.3343	0.10 Q		
20.27	0.3352	0.10 Q		
20.37	0.3360	0.10 Q		
20.47	0.3369	0.10 Q		
20.58	0.3377	0.10 Q		
20.68	0.3385	0.10 Q		
20.78	0.3393	0.09 Q		
20.88	0.3401	0.09 Q		
20.98	0.3409	0.09 Q		
21.08	0.3416	0.09 Q		
21.18	0.3424	0.09 Q		
21.29	0.3431	0.09 Q		
21.39	0.3439	0.09 Q		
21.49	0.3446	0.09 Q		
21.59	0.3453	0.09 Q		
21.69	0.3460	0.08 Q		
21.80	0.3467	0.08 Q		
21.90	0.3474	0.08 Q		
22.00	0.3481	0.08 Q		
22.10	0.3488	0.08 Q		
22.20	0.3495	0.08 Q		
22.30	0.3502	0.08 Q		
22.41	0.3508	0.08 Q		
22.51	0.3515	0.08 Q		
22.61	0.3521	0.08 Q		•
22.71	0.3528	0.08 Q		

22.81	0.3534	0.08 Q			
22.91	0.3540	0.07 Q			
23.02	0.3547	0.07 Q			
23.12	0.3553	0.07 Q			
23.22	0.3559	0.07 Q			
23.32	0.3565	0.07 Q			
23.42	0.3571	0.07 Q			
23.52	0.3577	0.07 Q			
23.62	0.3583	0.07 Q			
23.73	0.3589	0.07 Q			
23.83	0.3595	0.07 Q			
23.93	0.3601	0.07 Q			
24.03	0.3606	0.07 Q			
24.13	0.3609	0.00 Q			

TIME DURATION(minutes) OF PERCENTILES OF ESTIMATED PEAK FLOW RATE:

(Note: 100% of Peak Flow Rate estimate assumed to have an instantaneous time duration)

Percentile of Estimated	Duration				
Peak Flow Rate	(min	utes)			
=======================================	===	=======			
0%	1445.7				
10%	85.4				
20%	18.3				
30%	12.2				
40%	6.1				
50%	6.1				
60%	6.1				
70%	6.1				
80%	6.1				
90%	6.1				

Problem Descriptions: SERC Drainage Study Proposed Condition West Basin

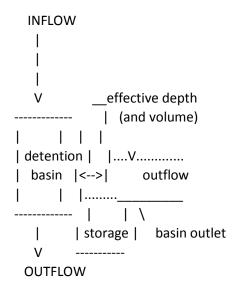
SPECIFIED BASIN CONDITIONS ARE AS FOLLOWS:

CONSTANT HYDROGRAPH TIME UNIT(MINUTES) = 6.100

DEAD STORAGE(AF) = 0.00

SPECIFIED DEAD STORAGE(AF) FILLED = 0.00

ASSUMED INITIAL DEPTH(FEET) IN STORAGE BASIN = 0.00



DEPTH-VS.-STORAGE AND DEPTH-VS.-DISCHARGE INFORMATION:

TOTAL NUMBER OF BASIN DEPTH INFORMATION ENTRIES = 5

*BASIN-DEPTH STORAGE OUTFLOW **BASIN-DEPTH STORAGE OUTFLOW *

- * (FEET) (ACRE-FEET) (CFS) ** (FEET) (ACRE-FEET) (CFS) *
- * 0.000 0.000 0.000** 0.050 0.000 0.020*
- * 0.200 0.001 0.470** 0.710 0.012 2.310*
- * 1.100 0.028 2.460**

BASIN STORAGE, OUTFLOW AND DEPTH ROUTING VALUES:

INTERVAL DEPTH {S-O*DT/2} {S+O*DT/2}

NUMBER (FEET) (ACRE-FEET) (ACRE-FEET)

- 1 0.00 0.00000 0.00000
- 2 0.05 -0.00001 0.00016
- 3 0.20 -0.00101 0.00294
- 4 0.71 0.00195 0.02136
- 5 1.10 0.01747 0.03814

WHERE S=STORAGE(AF);O=OUTFLOW(AF/MIN.);DT=UNIT INTERVAL(MIN.)

DETENTION BASIN ROUTING RESULTS:

NOTE: COMPUTED BASIN DEPTH, OUTFLOW, AND STORAGE QUANTITIES OCCUR AT THE GIVEN TIME. BASIN INFLOW VALUES REPRESENT THE

AVERAGE INFLOW DURING THE RECENT HYDROGRAPH UNIT INTERVAL.

TIME DEAD-STORAGE INFLOW EFFECTIVE OUTFLOW EFFECTIVE (HRS) FILLED(AF) (CFS) DEPTH(FT) (CFS) VOLUME(AF)

0.038 0.000 0.07 0.07 0.04 0.000 0.140 0.000 0.07 0.07 0.09 0.000 0.242 0.000 0.07 0.07 0.09 0.000 0.343 0.000 0.07 0.07 0.09 0.000 0.445 0.000 0.07 0.07 0.09 0.000 0.07 0.09 0.547 0.000 0.07 0.000 0.648 0.000 0.07 0.07 0.09 0.000 0.750 0.000 0.07 0.07 0.09 0.000 0.852 0.000 0.07 0.07 0.09 0.000 0.953 0.000 0.07 0.07 0.09 0.000 1.055 0.000 0.07 0.07 0.09 0.000 1.157 0.000 0.07 0.07 0.09 0.000 1.258 0.000 0.07 0.07 0.09 0.000 1.360 0.000 0.07 0.07 0.09 0.000 1.462 0.000 0.07 0.07 0.09 0.000 0.000 0.09 1.563 0.07 0.07 0.000 1.665 0.000 0.07 0.07 0.09 0.000 1.767 0.000 0.07 0.07 0.09 0.000 1.868 0.000 0.07 0.07 0.09 0.000 1.970 0.000 0.07 0.07 0.09 0.000 2.072 0.000 0.07 0.07 0.09 0.000 2.173 0.000 0.07 0.08 0.10 0.000 2.275 0.000 0.07 0.08 0.10 0.000 0.000 0.000 2.377 0.07 0.08 0.10 2.478 0.000 0.000 0.07 80.0 0.10 2.580 0.000 0.08 0.08 0.10 0.000 2.682 0.000 0.08 0.08 0.10 0.000 2.783 0.000 0.08 0.08 0.10 0.000 2.885 0.000 0.08 80.0 0.10 0.000 2.987 0.000 0.08 0.08 0.10 0.000 3.088 0.000 0.08 80.0 0.10 0.000 3.190 0.000 0.08 0.08 0.10 0.000 3.292 0.000 0.08 0.08 0.10 0.000 3.393 0.000 0.08 0.08 0.10 0.000 0.08 3.495 0.000 0.08 0.10 0.000 3.597 0.000 0.08 0.08 0.10 0.000 3.698 0.08 0.08 0.000 0.10 0.000 3.800 0.000 0.08 0.08 0.10 0.000

3.902

0.000

0.08

80.0

0.10

0.000

4.003	0.000	0.00	0.00	0.10	0.000
4.105	0.000	0.08 0.08	0.08	0.10	0.000
4.103	0.000	0.08	0.08	0.10	0.000
4.308	0.000	0.08	0.08	0.11	0.000
4.410	0.000	0.08	0.08	0.11	0.000
4.512	0.000	0.08	0.08	0.11	0.000
4.613	0.000	0.08	0.08	0.11	0.000
4.715	0.000	0.08	0.08	0.11	0.000
4.817	0.000	0.08	0.08	0.11	0.000
4.918	0.000	0.08	0.08	0.11	0.000
5.020	0.000	0.09	0.08	0.11	0.000
5.122	0.000	0.09	0.08	0.11	0.000
5.223	0.000	0.09	0.08	0.11	0.000
5.325	0.000	0.09	0.08	0.11	0.000
5.427	0.000	0.09	0.08	0.11	0.000
5.528	0.000	0.09	0.08	0.11	0.000
5.630	0.000	0.09	0.08	0.11	0.000
5.732	0.000	0.09	0.08	0.12	0.000
5.833	0.000	0.09	0.08	0.12	0.000
5.935	0.000	0.09	0.08	0.12	0.000
6.037	0.000	0.09	0.08	0.12	0.000
6.138	0.000	0.09	0.08	0.12	0.000
6.240	0.000	0.09	0.08	0.12	0.000
6.342	0.000	0.09	0.08	0.12	0.000
6.443	0.000	0.09	0.08	0.12	0.000
6.545	0.000	0.09	0.08	0.12	0.000
6.647	0.000	0.09	0.08	0.12	0.000
6.748	0.000	0.10	0.08	0.12	0.000
6.850	0.000	0.10	0.08	0.12	0.000
6.952	0.000	0.10	0.09	0.13	0.000
7.053	0.000	0.10	0.09	0.13	0.000
7.155	0.000	0.10	0.09	0.13	0.000
7.257	0.000	0.10	0.09	0.13	0.000
7.358	0.000	0.10	0.09	0.13	0.000
7.460	0.000	0.10	0.09	0.13	0.000
7.562	0.000	0.10	0.09	0.13	0.000
7.663	0.000	0.10	0.09	0.13	0.000
7.765	0.000	0.10	0.09	0.13	0.000
7.867	0.000	0.10	0.09	0.13	0.000
7.968	0.000	0.10	0.09	0.14	0.000
8.070	0.000	0.10	0.09	0.14	0.000
8.172	0.000	0.11	0.09	0.14	0.000
8.273	0.000	0.11	0.09	0.14	0.000
8.375	0.000	0.11	0.09	0.14	0.000

8.477	0.000	0 11	0.09	0.14	0.000
8.578	0.000	0.11 0.11	0.09	0.14 0.14	0.000
8.680	0.000	0.11	0.09	0.14	0.000
8.782	0.000	0.11	0.09	0.14	0.000
8.883	0.000	0.11	0.09	0.15	0.000
8.985	0.000	0.11	0.09	0.15	0.000
9.087	0.000	0.11	0.09	0.15	0.000
9.188	0.000	0.11	0.09	0.15	0.000
	0.000				
9.290 9.392	0.000	0.12 0.12	0.09 0.09	0.15 0.15	0.000
9.493	0.000	0.12	0.09	0.15	0.000
9.595	0.000				0.000
9.595	0.000	0.12	0.10	0.16	0.000
	0.000	0.12	0.10	0.16	
9.798		0.12	0.10	0.16	0.000
9.900	0.000	0.12	0.10	0.16	0.000
10.002	0.000	0.12	0.10	0.16	0.000
10.103	0.000	0.13	0.10	0.16	0.000
10.205	0.000	0.13	0.10	0.17	0.000
10.307	0.000	0.13	0.10	0.17	0.000
10.408	0.000	0.13	0.10	0.17	0.000
10.510	0.000	0.13	0.10	0.17	0.000
10.612	0.000	0.13	0.10	0.17	0.000
10.713	0.000	0.13	0.10	0.18	0.000
10.815	0.000	0.14	0.10	0.18	0.000
10.917	0.000	0.14	0.10	0.18	0.000
11.018	0.000	0.14	0.10	0.18	0.000
11.120	0.000	0.14	0.11	0.19	0.000
11.222	0.000	0.14	0.11	0.19	0.000
11.323	0.000	0.14	0.11	0.19	0.000
11.425	0.000	0.15	0.11	0.19	0.000
11.527	0.000	0.15	0.11	0.20	0.000
11.628	0.000	0.15	0.11	0.20	0.000
11.730	0.000	0.15	0.11	0.20	0.000
11.832	0.000	0.16	0.11	0.20	0.000
11.933	0.000	0.16	0.11	0.21	0.000
12.035	0.000	0.16	0.11	0.21	0.000
12.137	0.000	0.20	0.13	0.24	0.001
12.238	0.000	0.21 0.21	0.14 0.14	0.27	0.001
12.340	0.000			0.28	0.001
12.442	0.000	0.21	0.14	0.28	0.001
12.543	0.000	0.22	0.14	0.29	0.001
12.645	0.000	0.22	0.14	0.29	0.001
12.747	0.000	0.22	0.14	0.30	0.001
12.848	0.000	0.23	0.14	0.30	0.001

13.052 0.000 0.24 0.15 0.31 0.001 13.153 0.000 0.24 0.15 0.32 0.001 13.255 0.000 0.25 0.15 0.33 0.001 13.357 0.000 0.25 0.16 0.34 0.001 13.458 0.000 0.26 0.16 0.34 0.001 13.662 0.000 0.27 0.16 0.35 0.001 13.763 0.000 0.27 0.16 0.36 0.001 13.865 0.000 0.28 0.17 0.37 0.001 13.967 0.000 0.28 0.17 0.38 0.001 14.068 0.000 0.29 0.17 0.38 0.001 14.470 0.000 0.31 0.18 0.40 0.001 14.475 0.000 0.31 0.18 0.41 0.001 14.475 0.000 0.33 0.19 0.44 0.001 14.577 </th <th>12.950</th> <th>0.000</th> <th>0.23</th> <th>0.15</th> <th>0.31</th> <th>0.001</th>	12.950	0.000	0.23	0.15	0.31	0.001
13.153 0.000 0.24 0.15 0.32 0.001 13.255 0.000 0.24 0.15 0.32 0.001 13.357 0.000 0.25 0.16 0.34 0.001 13.458 0.000 0.26 0.16 0.34 0.001 13.560 0.000 0.27 0.16 0.35 0.001 13.763 0.000 0.27 0.16 0.36 0.001 13.865 0.000 0.28 0.17 0.37 0.001 14.068 0.000 0.28 0.17 0.39 0.001 14.170 0.000 0.32 0.18 0.40 0.001 14.272 0.000 0.31 0.18 0.41 0.001 14.373 0.000 0.32 0.19 0.42 0.001 14.475 0.000 0.33 0.19 0.44 0.001 14.577 0.000 0.34 0.20 0.45 0.001 14.588 </td <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
13.255 0.000 0.24 0.15 0.32 0.001 13.357 0.000 0.25 0.15 0.34 0.001 13.458 0.000 0.26 0.16 0.34 0.001 13.560 0.000 0.27 0.16 0.35 0.001 13.662 0.000 0.27 0.16 0.36 0.001 13.763 0.000 0.28 0.17 0.37 0.001 13.865 0.000 0.28 0.17 0.38 0.001 14.068 0.000 0.29 0.17 0.39 0.001 14.170 0.000 0.31 0.18 0.40 0.001 14.272 0.000 0.31 0.18 0.41 0.001 14.373 0.000 0.32 0.19 0.42 0.001 14.475 0.000 0.33 0.19 0.44 0.001 14.4780 0.000 0.37 0.20 0.48 0.001 14.983<						
13.357 0.000 0.25 0.15 0.34 0.001 13.458 0.000 0.25 0.16 0.34 0.001 13.560 0.000 0.27 0.16 0.35 0.001 13.662 0.000 0.27 0.16 0.35 0.001 13.763 0.000 0.28 0.17 0.37 0.001 13.865 0.000 0.28 0.17 0.38 0.001 14.068 0.000 0.29 0.17 0.39 0.001 14.170 0.000 0.30 0.18 0.40 0.001 14.373 0.000 0.31 0.18 0.41 0.001 14.475 0.000 0.33 0.19 0.42 0.001 14.475 0.000 0.33 0.19 0.44 0.001 14.475 0.000 0.34 0.20 0.45 0.001 14.475 0.000 0.36 0.20 0.47 0.001 14.577 </td <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
13.458 0.000 0.25 0.16 0.34 0.001 13.560 0.000 0.26 0.16 0.34 0.001 13.662 0.000 0.27 0.16 0.35 0.001 13.763 0.000 0.28 0.17 0.37 0.001 13.865 0.000 0.28 0.17 0.38 0.001 14.068 0.000 0.29 0.17 0.39 0.001 14.170 0.000 0.30 0.18 0.40 0.001 14.373 0.000 0.31 0.18 0.41 0.001 14.475 0.000 0.33 0.19 0.42 0.001 14.475 0.000 0.33 0.19 0.44 0.001 14.475 0.000 0.33 0.19 0.44 0.001 14.475 0.000 0.34 0.20 0.45 0.001 14.4780 0.000 0.37 0.20 0.48 0.001 14.983<						
13.560 0.000 0.26 0.16 0.34 0.001 13.662 0.000 0.27 0.16 0.35 0.001 13.763 0.000 0.28 0.17 0.37 0.001 13.865 0.000 0.28 0.17 0.38 0.001 13.967 0.000 0.28 0.17 0.39 0.001 14.068 0.000 0.29 0.17 0.39 0.001 14.170 0.000 0.30 0.18 0.40 0.001 14.373 0.000 0.31 0.18 0.41 0.001 14.475 0.000 0.33 0.19 0.42 0.001 14.577 0.000 0.34 0.20 0.45 0.001 14.678 0.000 0.36 0.20 0.47 0.001 14.780 0.000 0.37 0.20 0.48 0.001 14.983 0.000 0.43 0.22 0.53 0.001 15.187 </td <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
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14.577 0.000 0.34 0.20 0.45 0.001 14.678 0.000 0.36 0.20 0.47 0.001 14.780 0.000 0.37 0.20 0.48 0.001 14.882 0.000 0.39 0.21 0.49 0.001 14.983 0.000 0.40 0.21 0.51 0.001 15.085 0.000 0.43 0.22 0.53 0.001 15.187 0.000 0.45 0.22 0.54 0.001 15.288 0.000 0.49 0.23 0.57 0.002 15.390 0.000 0.51 0.24 0.59 0.002 15.492 0.000 0.50 0.24 0.60 0.002 15.593 0.000 0.54 0.24 0.62 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.102 0.000 4.30 1.06 1.91 0.026 16.203	14.373	0.000	0.32	0.19	0.42	0.001
14.678 0.000 0.36 0.20 0.47 0.001 14.780 0.000 0.37 0.20 0.48 0.001 14.882 0.000 0.39 0.21 0.49 0.001 14.983 0.000 0.40 0.21 0.51 0.001 15.085 0.000 0.43 0.22 0.53 0.001 15.187 0.000 0.45 0.22 0.54 0.001 15.288 0.000 0.49 0.23 0.57 0.002 15.390 0.000 0.51 0.24 0.59 0.002 15.492 0.000 0.50 0.24 0.60 0.002 15.593 0.000 0.54 0.24 0.62 0.002 15.695 0.000 0.65 0.27 0.68 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.102 0.000 4.30 1.06 1.91 0.026 16.203	14.475	0.000	0.33	0.19	0.44	0.001
14.780 0.000 0.37 0.20 0.48 0.001 14.882 0.000 0.39 0.21 0.49 0.001 14.983 0.000 0.40 0.21 0.51 0.001 15.085 0.000 0.43 0.22 0.53 0.001 15.187 0.000 0.45 0.22 0.54 0.001 15.288 0.000 0.49 0.23 0.57 0.002 15.390 0.000 0.51 0.24 0.59 0.002 15.492 0.000 0.50 0.24 0.60 0.002 15.593 0.000 0.54 0.24 0.62 0.002 15.695 0.000 0.65 0.27 0.68 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.407	14.577	0.000	0.34	0.20	0.45	0.001
14.882 0.000 0.39 0.21 0.49 0.001 14.983 0.000 0.40 0.21 0.51 0.001 15.085 0.000 0.43 0.22 0.53 0.001 15.187 0.000 0.45 0.22 0.54 0.001 15.288 0.000 0.49 0.23 0.57 0.002 15.390 0.000 0.51 0.24 0.59 0.002 15.492 0.000 0.50 0.24 0.60 0.002 15.593 0.000 0.54 0.24 0.62 0.002 15.695 0.000 0.65 0.27 0.68 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.000 0.000 1.43 0.45 1.21 0.006 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.407	14.678	0.000	0.36	0.20	0.47	0.001
14.983 0.000 0.40 0.21 0.51 0.001 15.085 0.000 0.43 0.22 0.53 0.001 15.187 0.000 0.45 0.22 0.54 0.001 15.288 0.000 0.49 0.23 0.57 0.002 15.390 0.000 0.51 0.24 0.60 0.002 15.492 0.000 0.50 0.24 0.62 0.002 15.593 0.000 0.54 0.24 0.62 0.002 15.695 0.000 0.65 0.27 0.68 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.000 0.000 1.43 0.45 1.21 0.006 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.48 0.23 0.81 0.002 16.508 </td <td>14.780</td> <td>0.000</td> <td>0.37</td> <td>0.20</td> <td>0.48</td> <td>0.001</td>	14.780	0.000	0.37	0.20	0.48	0.001
15.085 0.000 0.43 0.22 0.53 0.001 15.187 0.000 0.45 0.22 0.54 0.001 15.288 0.000 0.49 0.23 0.57 0.002 15.390 0.000 0.51 0.24 0.59 0.002 15.492 0.000 0.50 0.24 0.62 0.002 15.593 0.000 0.54 0.24 0.62 0.002 15.695 0.000 0.65 0.27 0.68 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.000 0.000 1.43 0.45 1.21 0.006 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 </td <td>14.882</td> <td>0.000</td> <td>0.39</td> <td>0.21</td> <td>0.49</td> <td>0.001</td>	14.882	0.000	0.39	0.21	0.49	0.001
15.187 0.000 0.45 0.22 0.54 0.001 15.288 0.000 0.49 0.23 0.57 0.002 15.390 0.000 0.51 0.24 0.59 0.002 15.492 0.000 0.50 0.24 0.60 0.002 15.593 0.000 0.54 0.24 0.62 0.002 15.695 0.000 0.65 0.27 0.68 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.000 0.000 1.43 0.45 1.21 0.006 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 </td <td>14.983</td> <td>0.000</td> <td>0.40</td> <td>0.21</td> <td>0.51</td> <td>0.001</td>	14.983	0.000	0.40	0.21	0.51	0.001
15.288 0.000 0.49 0.23 0.57 0.002 15.390 0.000 0.51 0.24 0.59 0.002 15.492 0.000 0.50 0.24 0.60 0.002 15.593 0.000 0.54 0.24 0.62 0.002 15.695 0.000 0.65 0.27 0.68 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.000 0.000 1.43 0.45 1.21 0.006 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.813	15.085	0.000	0.43	0.22	0.53	0.001
15.390 0.000 0.51 0.24 0.59 0.002 15.492 0.000 0.50 0.24 0.60 0.002 15.593 0.000 0.54 0.24 0.62 0.002 15.695 0.000 0.65 0.27 0.68 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.000 0.000 1.43 0.45 1.21 0.006 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.813 </td <td>15.187</td> <td>0.000</td> <td>0.45</td> <td>0.22</td> <td>0.54</td> <td>0.001</td>	15.187	0.000	0.45	0.22	0.54	0.001
15.492 0.000 0.50 0.24 0.60 0.002 15.593 0.000 0.54 0.24 0.62 0.002 15.695 0.000 0.65 0.27 0.68 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.000 0.000 1.43 0.45 1.21 0.006 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.813 0.000 0.38 0.21 0.51 0.001 16.915 </td <td>15.288</td> <td>0.000</td> <td>0.49</td> <td>0.23</td> <td>0.57</td> <td>0.002</td>	15.288	0.000	0.49	0.23	0.57	0.002
15.593 0.000 0.54 0.24 0.62 0.002 15.695 0.000 0.65 0.27 0.68 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.000 0.000 1.43 0.45 1.21 0.006 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.813 0.000 0.38 0.21 0.51 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 </td <td>15.390</td> <td>0.000</td> <td>0.51</td> <td>0.24</td> <td>0.59</td> <td>0.002</td>	15.390	0.000	0.51	0.24	0.59	0.002
15.695 0.000 0.65 0.27 0.68 0.002 15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.000 0.000 1.43 0.45 1.21 0.006 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.712 0.000 0.38 0.21 0.51 0.001 16.813 0.000 0.35 0.20 0.48 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 </td <td>15.492</td> <td>0.000</td> <td>0.50</td> <td>0.24</td> <td>0.60</td> <td>0.002</td>	15.492	0.000	0.50	0.24	0.60	0.002
15.797 0.000 0.74 0.29 0.76 0.003 15.898 0.000 1.04 0.36 0.92 0.004 16.000 0.000 1.43 0.45 1.21 0.006 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.712 0.000 0.38 0.21 0.51 0.001 16.813 0.000 0.35 0.20 0.48 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 </td <td>15.593</td> <td>0.000</td> <td>0.54</td> <td>0.24</td> <td>0.62</td> <td>0.002</td>	15.593	0.000	0.54	0.24	0.62	0.002
15.898 0.000 1.04 0.36 0.92 0.004 16.000 0.000 1.43 0.45 1.21 0.006 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.712 0.000 0.38 0.21 0.51 0.001 16.813 0.000 0.35 0.20 0.48 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 </td <td>15.695</td> <td>0.000</td> <td>0.65</td> <td>0.27</td> <td>0.68</td> <td>0.002</td>	15.695	0.000	0.65	0.27	0.68	0.002
16.000 0.000 1.43 0.45 1.21 0.006 16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.712 0.000 0.38 0.21 0.51 0.001 16.813 0.000 0.35 0.20 0.48 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	15.797	0.000	0.74	0.29	0.76	0.003
16.102 0.000 4.30 1.06 1.91 0.026 16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.712 0.000 0.38 0.21 0.51 0.001 16.813 0.000 0.35 0.20 0.48 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	15.898	0.000	1.04	0.36	0.92	0.004
16.203 0.000 0.85 0.75 2.39 0.013 16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.712 0.000 0.38 0.21 0.51 0.001 16.813 0.000 0.35 0.20 0.48 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	16.000	0.000	1.43	0.45	1.21	0.006
16.305 0.000 0.59 0.36 1.68 0.004 16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.712 0.000 0.38 0.21 0.51 0.001 16.813 0.000 0.35 0.20 0.48 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	16.102	0.000	4.30	1.06	1.91	0.026
16.407 0.000 0.48 0.23 0.81 0.002 16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.712 0.000 0.38 0.21 0.51 0.001 16.813 0.000 0.35 0.20 0.48 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	16.203	0.000	0.85	0.75	2.39	0.013
16.508 0.000 0.47 0.23 0.57 0.002 16.610 0.000 0.42 0.22 0.55 0.001 16.712 0.000 0.38 0.21 0.51 0.001 16.813 0.000 0.35 0.20 0.48 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	16.305	0.000	0.59	0.36	1.68	0.004
16.610 0.000 0.42 0.22 0.55 0.001 16.712 0.000 0.38 0.21 0.51 0.001 16.813 0.000 0.35 0.20 0.48 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	16.407	0.000	0.48	0.23	0.81	0.002
16.712 0.000 0.38 0.21 0.51 0.001 16.813 0.000 0.35 0.20 0.48 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	16.508	0.000	0.47	0.23	0.57	0.002
16.813 0.000 0.35 0.20 0.48 0.001 16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	16.610	0.000	0.42	0.22	0.55	0.001
16.915 0.000 0.33 0.19 0.45 0.001 17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	16.712	0.000	0.38	0.21	0.51	0.001
17.017 0.000 0.31 0.18 0.42 0.001 17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	16.813	0.000	0.35	0.20	0.48	0.001
17.118 0.000 0.29 0.17 0.40 0.001 17.220 0.000 0.27 0.17 0.38 0.001	16.915	0.000	0.33	0.19	0.45	0.001
17.220 0.000 0.27 0.17 0.38 0.001	17.017	0.000	0.31	0.18	0.42	0.001
	17.118	0.000	0.29	0.17	0.40	0.001
17.322 0.000 0.26 0.16 0.36 0.001	17.220	0.000		0.17	0.38	0.001
	17.322	0.000	0.26	0.16	0.36	0.001

17.423	0.000	0.25	0.16	0.34	0.001
17.525	0.000	0.23	0.15	0.34	0.001
17.627	0.000	0.23	0.15	0.32	0.001
17.728	0.000	0.23	0.13	0.32	0.001
17.728	0.000	0.23	0.14	0.30	0.001
17.830	0.000	0.22	0.14	0.29	0.001
18.033	0.000	0.21	0.14	0.29	0.001
18.135	0.000	0.21	0.13	0.24	0.001
18.237 18.338	0.000	0.15	0.11	0.21	0.000
		0.15	0.11	0.20	
18.440	0.000	0.15	0.11	0.20	0.000
18.542	0.000	0.14	0.11	0.19	0.000
18.643	0.000	0.14	0.10	0.19	0.000
18.745	0.000	0.14	0.10	0.18	0.000
18.847	0.000	0.13	0.10	0.18	0.000
18.948	0.000	0.13	0.10	0.17	0.000
19.050	0.000	0.13	0.10	0.17	0.000
19.152	0.000	0.12	0.10	0.16	0.000
19.253	0.000	0.12	0.10	0.16	0.000
19.355	0.000	0.12	0.10	0.16	0.000
19.457	0.000	0.12	0.09	0.15	0.000
19.558	0.000	0.11	0.09	0.15	0.000
19.660	0.000	0.11	0.09	0.15	0.000
19.762	0.000	0.11	0.09	0.15	0.000
19.863	0.000	0.11	0.09	0.14	0.000
19.965	0.000	0.11	0.09	0.14	0.000
20.067	0.000	0.10	0.09	0.14	0.000
20.168	0.000	0.10	0.09	0.14	0.000
20.270	0.000	0.10	0.09	0.13	0.000
20.372	0.000	0.10	0.09	0.13	0.000
20.473	0.000	0.10	0.09	0.13	0.000
20.575	0.000	0.10	0.09	0.13	0.000
20.677	0.000	0.10	0.09	0.13	0.000
20.778	0.000	0.09	0.08	0.12	0.000
20.880	0.000	0.09	0.08	0.12	0.000
20.982	0.000	0.09	0.08	0.12	0.000
21.083	0.000	0.09	0.08	0.12	0.000
21.185	0.000	0.09	0.08	0.12	0.000
21.287	0.000	0.09	0.08	0.12	0.000
21.388	0.000	0.09	0.08	0.11	0.000
21.490	0.000	0.09	0.08	0.11	0.000
21.592	0.000	0.09	0.08	0.11	0.000
21.693	0.000	0.08	0.08	0.11	0.000
21.795	0.000	0.08	0.08	0.11	0.000

21.897	0.000	0.08	0.08	0.11	0.000	
21.998	0.000	0.08	0.08	0.11	0.000	
22.100	0.000	0.08	0.08	0.11	0.000	
22.202	0.000	0.08	0.08	0.10	0.000	
22.303	0.000	0.08	0.08	0.10	0.000	
22.405	0.000	0.08	0.08	0.10	0.000	
22.507	0.000	0.08	0.08	0.10	0.000	
22.608	0.000	0.08	0.08	0.10	0.000	
22.710	0.000	0.08	0.08	0.10	0.000	
22.812	0.000	0.08	0.08	0.10	0.000	
22.913	0.000	0.07	0.08	0.10	0.000	
23.015	0.000	0.07	0.08	0.10	0.000	
23.117	0.000	0.07	0.07	0.10	0.000	
23.218	0.000	0.07	0.07	0.09	0.000	
23.320	0.000	0.07	0.07	0.09	0.000	
23.422	0.000	0.07	0.07	0.09	0.000	
23.523	0.000	0.07	0.07	0.09	0.000	
23.625	0.000	0.07	0.07	0.09	0.000	
23.727	0.000	0.07	0.07	0.09	0.000	
23.828	0.000	0.07	0.07	0.09	0.000	
23.930	0.000	0.07	0.07	0.09	0.000	
24.032	0.000	0.07	0.07	0.09	0.000	
24.133	0.000	0.00	0.00	0.04	0.000	
24.235	0.000	0.00	0.00	0.00	0.000	

North Eastern Subcatchment (Off-Site) Proposed System

RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE

(Reference: 1986 ORANGE COUNTY HYDROLOGY CRITERION) (c) Copyright 1983-2014 Advanced Engineering Software (aes)

(c) Copyright 1983-2014 Advanced Engineering Software (ae

Ver. 21.0 Release Date: 06/01/2014 License ID 1501

FILE NAME: PNEAST.DAT

TIME/DATE OF STUDY: 07:08 10/11/2016

USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION:

--*TIME-OF-CONCENTRATION MODEL*--

USER SPECIFIED STORM EVENT(YEAR) = 100.00

SPECIFIED MINIMUM PIPE SIZE(INCH) = 6.00

SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE = 0.90

DATA BANK RAINFALL USED

ANTECEDENT MOISTURE CONDITION (AMC) III ASSUMED FOR RATIONAL METHOD

USER-DEFINED STREET-SECTIONS FOR COUPLED PIPEFLOW AND STREETFLOW MODEL
HALF- CROWN TO STREET-CROSSFALL: CURB GUTTER-GEOMETRIES: MANNING
WIDTH CROSSFALL IN- / OUT-/PARK- HEIGHT WIDTH LIP HIKE FACTOR

NO. (FT) (FT) SIDE / SIDE / WAY (FT) (FT) (FT) (FT)

1 30.0 20.0 0.018/0.018/0.020 0.67 2.00 0.0313 0.167 0.0150

GLOBAL STREET FLOW-DEPTH CONSTRAINTS:

- 1. Relative Flow-Depth = 0.00 FEET
 - as (Maximum Allowable Street Flow Depth) (Top-of-Curb)
- 2. (Depth)*(Velocity) Constraint = 6.0 (FT*FT/S)
- *SIZE PIPE WITH A FLOW CAPACITY GREATER THAN

OR EQUAL TO THE UPSTREAM TRIBUTARY PIPE.*

*USER-SPECIFIED MINIMUM TOPOGRAPHIC SLOPE ADJUSTMENT NOT SELECTED

FLOW PROCESS FROM NODE 300.00 TO NODE 301.00 IS CODE = 21

>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS

>>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<<

```
INITIAL SUBAREA FLOW-LENGTH(FEET) = 633.00
ELEVATION DATA: UPSTREAM(FEET) = 72.90 DOWNSTREAM(FEET) = 71.80
Tc = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]**0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 33.218
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 2.091
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                      Ap SCS Tc
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
  LAND USE
AGRICULTURAL FAIR COVER
"PASTURE, DRYLAND"
                        0.99 0.40 1.000 69 33.22
                    Α
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 1.000
SUBAREA RUNOFF(CFS) = 1.50
TOTAL AREA(ACRES) = 0.99 PEAK FLOW RATE(CFS) = 1.50
 ************************
FLOW PROCESS FROM NODE 301.00 TO NODE 303.00 IS CODE = 31
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<
______
ELEVATION DATA: UPSTREAM(FEET) = 71.80 DOWNSTREAM(FEET) = 68.50
FLOW LENGTH(FEET) = 91.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 9.0 INCH PIPE IS 4.5 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 6.75
ESTIMATED PIPE DIAMETER(INCH) = 9.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
                1.50
PIPE TRAVEL TIME(MIN.) = 0.22 Tc(MIN.) = 33.44
LONGEST FLOWPATH FROM NODE 300.00 TO NODE 303.00 = 724.00 FEET.
*************************
FLOW PROCESS FROM NODE 303.00 TO NODE 304.00 IS CODE = 41
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING USER-SPECIFIED PIPESIZE (EXISTING ELEMENT)<
______
ELEVATION DATA: UPSTREAM(FEET) = 68.50 DOWNSTREAM(FEET) = 64.50
FLOW LENGTH(FEET) = 35.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 24.0 INCH PIPE IS 2.4 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 9.23
GIVEN PIPE DIAMETER(INCH) = 24.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) = 1.50
```

END OF RATIONAL METHOD ANALYSIS

N	ON-HOMOGENEOUS WATERSHED AREA-AVERAGED LOSS RATE (Fm)
	AND LOW LOSS FRACTION ESTIMATIONS
(C)	Copyright 1989-2014 Advanced Engineering Software (aes)
•	Ver. 21.0 Release Date: 06/01/2014 License ID 1501
*****	*******************************
Problei	m Descriptions:
	Prainage Study
Propos	sed Condition
North	East
*** NO	N-HOMOGENEOUS WATERSHED AREA-AVERAGED LOSS RATE (Fm)
	LOW LOSS FRACTION ESTIMATIONS FOR AMC III:
AND	
TOTA	LOW LOSS FRACTION ESTIMATIONS FOR AMC III:
TOTA	LOW LOSS FRACTION ESTIMATIONS FOR AMC III: L 24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) COVER AREA PERCENT OF SCS CURVE LOSS RATE
TOTA	LOW LOSS FRACTION ESTIMATIONS FOR AMC III: L 24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) COVER AREA PERCENT OF SCS CURVE LOSS RATE
TOTA SOIL-	LOW LOSS FRACTION ESTIMATIONS FOR AMC III: L 24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) COVER AREA PERCENT OF SCS CURVE LOSS RATE E (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD
TOTA SOIL-	LOW LOSS FRACTION ESTIMATIONS FOR AMC III: L 24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) COVER AREA PERCENT OF SCS CURVE LOSS RATE E (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD
TOTA SOIL- TYP 1 TOTA	LOW LOSS FRACTION ESTIMATIONS FOR AMC III: L 24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) COVER AREA PERCENT OF SCS CURVE LOSS RATE E (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD 0.99 100.00 49.(AMC II) 10.000 0.431

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Proble	m Descript	tions:						
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	L CATCHN		-			99		
	LOSS RATE			•	9.990			
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*****	*****	*****	***	*****	****	*****	*****	*********
TIME	VOLUME	E Q	0.	2.5	5.0	7.5	10.0	
(HOUR	S) (AF)	(CFS)						
•								
0.36	0.0000	0.00	Q	•	•			
0.36	0.0000 0.0015					 		
0.36 0.92	0.0015		Q					

2.60	0.0108	0.07 Q					
3.15	0.0141	0.07 Q					
3.71	0.0175	0.07 Q					
4.27	0.0209	0.08 Q					
4.83	0.0245	0.08 Q					
5.39	0.0281	0.08 Q					
5.95	0.0319	0.08 Q					
6.51	0.0358	0.09 Q					
7.06	0.0399	0.09 Q					
7.62	0.0441	0.09 Q					
8.18	0.0484	0.10 Q	•				
8.74	0.0530	0.10 Q	•				
9.30	0.0578	0.10 Q		•			
9.86	0.0628	0.11 Q					
10.41	0.0681	0.12 Q		•		•	
10.97	0.0737	0.13 Q		•		•	
11.53	0.0797	0.13 Q		•		•	
12.09	0.0861	0.15 Q		•		•	
12.65	0.0937	0.18 Q		•		•	
13.21	0.1030	0.22 Q			•		
13.77	0.1133	0.23 Q		•	•	•	
14.32	0.1250	0.27 .Q		•		•	
14.88	0.1384	0.31 .Q		•		•	
15.44	0.1552	0.42 .Q					
16.00	0.1766	0.51 . Q	•				
16.56	0.2228	1.50 . Q	•	•		•	
17.12	0.2654	0.35 .Q	•	•		•	
17.68	0.2793	0.25 .Q	•				
18.23	0.2898	0.20 Q	•	•	•	•	
18.79	0.2977	0.14 Q	•	•	•	•	
19.35	0.3037	0.12 Q	•	•	•	•	
19.91	0.3090	0.11 Q	•	•	•	•	
20.47	0.3138	0.10 Q	•	•	•	•	
21.03	0.3182	0.09 Q	•	•	•	•	
21.58	0.3222	0.08 Q	•	•	•	•	
22.14	0.3260	0.08 Q	•	•	•	•	
22.70	0.3296	0.07 Q	•	•	•	•	
23.26	0.3329	0.07 Q	•	•	٠	•	
23.82	0.3361	0.07 Q	•	•	•	•	
24.38 24.94	0.3392 0.3407	0.06 Q 0.00 Q	•	•	•	•	
24.34	0.3407	0.00 Q 	•	•	•	•	

(Note: 100% of Peak Flow Rate estimate assumed to have an instantaneous time duration)

Percentile of Estimated	Duration
Peak Flow Rate	(minutes)
=======================================	==== ======
0%	1440.9
10%	368.6
20%	167.5
30%	67.0
40%	33.5
50%	33.5
60%	33.5
70%	33.5
80%	33.5
90%	33.5

South Eastern Subcatchment (On-Site) Proposed System

RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE

(Reference: 1986 ORANGE COUNTY HYDROLOGY CRITERION) (c) Copyright 1983-2014 Advanced Engineering Software (aes)

Ver. 21.0 Release Date: 06/01/2014 License ID 1501

FILE NAME: C:\AES\PSEAST.DAT

TIME/DATE OF STUDY: 14:05 10/13/2016

USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION:

--*TIME-OF-CONCENTRATION MODEL*--

USER SPECIFIED STORM EVENT(YEAR) = 100.00 SPECIFIED MINIMUM PIPE SIZE(INCH) = 6.00

SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE = 0.90

DATA BANK RAINFALL USED

ANTECEDENT MOISTURE CONDITION (AMC) III ASSUMED FOR RATIONAL METHOD

USER-DEFINED STREET-SECTIONS FOR COUPLED PIPEFLOW AND STREETFLOW MODEL
HALF- CROWN TO STREET-CROSSFALL: CURB GUTTER-GEOMETRIES: MANNING
WIDTH CROSSFALL IN- / OUT-/PARK- HEIGHT WIDTH LIP HIKE FACTOR

NO. (FT) (FT) SIDE / SIDE / WAY (FT) (FT) (FT) (FT) (n)

1 30.0 20.0 0.018/0.018/0.020 0.67 2.00 0.0313 0.167 0.0150

GLOBAL STREET FLOW-DEPTH CONSTRAINTS:

- 1. Relative Flow-Depth = 0.00 FEET
 - as (Maximum Allowable Street Flow Depth) (Top-of-Curb)
- 2. (Depth)*(Velocity) Constraint = 6.0 (FT*FT/S)
- *SIZE PIPE WITH A FLOW CAPACITY GREATER THAN

OR EQUAL TO THE UPSTREAM TRIBUTARY PIPE.*

*USER-SPECIFIED MINIMUM TOPOGRAPHIC SLOPE ADJUSTMENT NOT SELECTED

FLOW PROCESS FROM NODE 500.00 TO NODE 501.00 IS CODE = 21

```
INITIAL SUBAREA FLOW-LENGTH(FEET) = 187.00
ELEVATION DATA: UPSTREAM(FEET) = 73.00 DOWNSTREAM(FEET) = 71.50
Tc = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]**0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 6.468
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 5.339
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                     Ap SCS Tc
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
  LAND USE
COMMERCIAL
                     0.31 0.40 0.100 52 6.47
AGRICULTURAL FAIR COVER
"PASTURE,DRYLAND"
                        0.11 0.40 1.000 69 15.02
                   Α
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.345
SUBAREA RUNOFF(CFS) = 1.96
TOTAL AREA(ACRES) = 0.42 PEAK FLOW RATE(CFS) = 1.96
*************************
FLOW PROCESS FROM NODE 501.00 TO NODE 502.00 IS CODE = 31
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<
______
ELEVATION DATA: UPSTREAM(FEET) = 69.00 DOWNSTREAM(FEET) = 67.30
FLOW LENGTH(FEET) = 331.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 12.0 INCH PIPE IS 8.2 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 3.43
ESTIMATED PIPE DIAMETER(INCH) = 12.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
                1.96
PIPE TRAVEL TIME(MIN.) = 1.61 Tc(MIN.) = 8.08
LONGEST FLOWPATH FROM NODE 500.00 TO NODE 502.00 = 518.00 FEET.
****************************
FLOW PROCESS FROM NODE 502.00 TO NODE 502.00 IS CODE = 82
>>>>ADD SUBAREA RUNOFF TO MAINLINE, AT MAINLINE Tc,<<<<
>>>>(AND COMPUTE INITIAL SUBAREA RUNOFF)<
______
INITIAL SUBAREA FLOW-LENGTH(FEET) = 212.00
ELEVATION DATA: UPSTREAM(FEET) = 72.70 DOWNSTREAM(FEET) = 71.30
Tc = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]**0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 7.070
```

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* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 5.073
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp Ap SCS Tc
  LAND USE
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
COMMERCIAL
                     0.24 0.40 0.100 52 7.07
AGRICULTURAL FAIR COVER
"PASTURE, DRYLAND"
                   Α
                       SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.359
SUBAREA AREA(ACRES) = 0.33 INITIAL SUBAREA RUNOFF(CFS) = 1.48
** ADD SUBAREA RUNOFF TO MAINLINE AT MAINLINE Tc:
MAINLINE Tc(MIN.) = 8.08
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 4.701
SUBAREA AREA(ACRES) = 0.33 SUBAREA RUNOFF(CFS) = 1.37
EFFECTIVE AREA(ACRES) = 0.75 AREA-AVERAGED Fm(INCH/HR) = 0.14
AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.35
TOTAL AREA(ACRES) = 0.8
                        PEAK FLOW RATE(CFS) = 3.09
*******************************
FLOW PROCESS FROM NODE 502.00 TO NODE 503.00 IS CODE = 31
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<
______
ELEVATION DATA: UPSTREAM(FEET) = 66.80 DOWNSTREAM(FEET) = 66.50
FLOW LENGTH(FEET) = 54.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 15.0 INCH PIPE IS 9.0 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 4.00
ESTIMATED PIPE DIAMETER(INCH) = 15.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
                3.09
PIPE TRAVEL TIME(MIN.) = 0.23 Tc(MIN.) = 8.30
LONGEST FLOWPATH FROM NODE 500.00 TO NODE 503.00 = 572.00 FEET.
***********************************
FLOW PROCESS FROM NODE 503.00 TO NODE 507.00 IS CODE = 31
-----
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<<<<<
>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<
______
ELEVATION DATA: UPSTREAM(FEET) = 66.40 DOWNSTREAM(FEET) = 66.00
FLOW LENGTH(FEET) = 79.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 15.0 INCH PIPE IS 9.3 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 3.85
```

```
ESTIMATED PIPE DIAMETER(INCH) = 15.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
                3.09
PIPE TRAVEL TIME(MIN.) = 0.34 Tc(MIN.) = 8.64
LONGEST FLOWPATH FROM NODE 500.00 TO NODE 507.00 = 651.00 FEET.
************************************
FLOW PROCESS FROM NODE 507.00 TO NODE 507.00 IS CODE = 1
>>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE<
______
TOTAL NUMBER OF STREAMS = 2
CONFLUENCE VALUES USED FOR INDEPENDENT STREAM 1 ARE:
TIME OF CONCENTRATION(MIN.) = 8.64
RAINFALL INTENSITY(INCH/HR) = 4.52
AREA-AVERAGED Fm(INCH/HR) = 0.14
AREA-AVERAGED Fp(INCH/HR) = 0.40
AREA-AVERAGED Ap = 0.35
EFFECTIVE STREAM AREA(ACRES) = 0.75
TOTAL STREAM AREA(ACRES) = 0.75
PEAK FLOW RATE(CFS) AT CONFLUENCE =
                                 3.09
*****************************
FLOW PROCESS FROM NODE 504.00 TO NODE 505.00 IS CODE = 21
>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<
>>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<<
______
INITIAL SUBAREA FLOW-LENGTH(FEET) = 213.00
ELEVATION DATA: UPSTREAM(FEET) = 72.70 DOWNSTREAM(FEET) = 71.30
Tc = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]**0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 7.090
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 5.065
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                     Ap SCS Tc
  LAND USE
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
COMMERCIAL
                     0.32  0.40  0.100  52  7.09
AGRICULTURAL FAIR COVER
"PASTURE, DRYLAND"
                   Α
                        0.15 0.40 1.000 69 16.47
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.386
SUBAREA RUNOFF(CFS) = 2.07
TOTAL AREA(ACRES) = 0.47 PEAK FLOW RATE(CFS) =
```

```
FLOW PROCESS FROM NODE 505.00 TO NODE 506.00 IS CODE = 31
______
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<
______
ELEVATION DATA: UPSTREAM(FEET) = 68.80 DOWNSTREAM(FEET) = 66.90
FLOW LENGTH(FEET) = 382.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 12.0 INCH PIPE IS 8.7 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 3.42
ESTIMATED PIPE DIAMETER(INCH) = 12.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
                2.07
PIPE TRAVEL TIME(MIN.) = 1.86 Tc(MIN.) = 8.95
LONGEST FLOWPATH FROM NODE 504.00 TO NODE 506.00 = 595.00 FEET.
*****************************
FLOW PROCESS FROM NODE 506.00 TO NODE 506.00 IS CODE = 82
______
>>>>ADD SUBAREA RUNOFF TO MAINLINE, AT MAINLINE Tc,<<<<
>>>>(AND COMPUTE INITIAL SUBAREA RUNOFF)<
______
INITIAL SUBAREA FLOW-LENGTH(FEET) = 226.00
ELEVATION DATA: UPSTREAM(FEET) = 72.70 DOWNSTREAM(FEET) = 70.80
Tc = K^*[(LENGTH^{**} 3.00)/(ELEVATION CHANGE)]^{**}0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 6.912
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 5.140
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                     Ap SCS Tc
  LAND USE
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
COMMERCIAL
                     Α
AGRICULTURAL FAIR COVER
                       0.09 0.40 1.000 69 16.05
"PASTURE, DRYLAND"
                  Α
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.359
SUBAREA AREA(ACRES) = 0.32 INITIAL SUBAREA RUNOFF(CFS) = 1.45
** ADD SUBAREA RUNOFF TO MAINLINE AT MAINLINE Tc:
MAINLINE Tc(MIN.) = 8.95
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 4.431
SUBAREA AREA(ACRES) = 0.32 SUBAREA RUNOFF(CFS) = 1.25
EFFECTIVE AREA(ACRES) = 0.79 AREA-AVERAGED Fm(INCH/HR) = 0.15
AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.38
TOTAL AREA(ACRES) = 0.8
                        PEAK FLOW RATE(CFS) =
```

************************** FLOW PROCESS FROM NODE 506.00 TO NODE 507.00 IS CODE = 31 >>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA< >>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)< ______ ELEVATION DATA: UPSTREAM(FEET) = 66.90 DOWNSTREAM(FEET) = 66.10 FLOW LENGTH(FEET) = 49.00 MANNING'S N = 0.013DEPTH OF FLOW IN 12.0 INCH PIPE IS 7.4 INCHES PIPE-FLOW VELOCITY(FEET/SEC.) = 5.96 ESTIMATED PIPE DIAMETER(INCH) = 12.00 NUMBER OF PIPES = 1 PIPE-FLOW(CFS) = 3.05 PIPE TRAVEL TIME(MIN.) = 0.14 Tc(MIN.) = 9.09LONGEST FLOWPATH FROM NODE 504.00 TO NODE 507.00 = 644.00 FEET. FLOW PROCESS FROM NODE 507.00 TO NODE 507.00 IS CODE = 1 >>>>DESIGNATE INDEPENDENT STREAM FOR CONFLUENCE <<<< >>>>AND COMPUTE VARIOUS CONFLUENCED STREAM VALUES< ______ TOTAL NUMBER OF STREAMS = 2 CONFLUENCE VALUES USED FOR INDEPENDENT STREAM 2 ARE: TIME OF CONCENTRATION(MIN.) = 9.09RAINFALL INTENSITY(INCH/HR) = 4.39 AREA-AVERAGED Fm(INCH/HR) = 0.15AREA-AVERAGED Fp(INCH/HR) = 0.40AREA-AVERAGED Ap = 0.38 EFFECTIVE STREAM AREA(ACRES) = 0.79 TOTAL STREAM AREA(ACRES) = 0.79 PEAK FLOW RATE(CFS) AT CONFLUENCE = ** CONFLUENCE DATA ** Q Tc Intensity Fp(Fm) Ap Ae HEADWATER STREAM NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE 3.09 8.64 4.522 0.40(0.14) 0.35 0.8 500.00 1

RAINFALL INTENSITY AND TIME OF CONCENTRATION RATIO

CONFLUENCE FORMULA USED FOR 2 STREAMS.

** PEAK FLOW RATE TABLE **

2

STREAM Q To Intensity Fp(Fm) Ap Ae HEADWATER

3.05 9.09 4.393 0.40(0.15) 0.38 0.8 504.00

```
NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE
      6.08 8.64 4.522 0.40(0.15) 0.36 1.5 500.00
  1
  2
      6.05 9.09 4.393 0.40(0.15) 0.36 1.5 504.00
COMPUTED CONFLUENCE ESTIMATES ARE AS FOLLOWS:
PEAK FLOW RATE(CFS) = 6.08 Tc(MIN.) = 8.64
EFFECTIVE AREA(ACRES) = 1.51 AREA-AVERAGED Fm(INCH/HR) = 0.15
AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.36
TOTAL AREA(ACRES) =
                    1.5
LONGEST FLOWPATH FROM NODE 500.00 TO NODE 507.00 = 651.00 FEET.
*************************
FLOW PROCESS FROM NODE 507.00 TO NODE 508.00 IS CODE = 31
>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA<
>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<
______
ELEVATION DATA: UPSTREAM(FEET) = 65.50 DOWNSTREAM(FEET) = 65.30
FLOW LENGTH(FEET) = 48.00 MANNING'S N = 0.013
DEPTH OF FLOW IN 18.0 INCH PIPE IS 13.9 INCHES
PIPE-FLOW VELOCITY(FEET/SEC.) = 4.14
ESTIMATED PIPE DIAMETER(INCH) = 18.00 NUMBER OF PIPES = 1
PIPE-FLOW(CFS) =
                6.08
PIPE TRAVEL TIME(MIN.) = 0.19 Tc(MIN.) = 8.84
LONGEST FLOWPATH FROM NODE 500.00 TO NODE 508.00 = 699.00 FEET.
FLOW PROCESS FROM NODE 508.00 TO NODE 508.00 IS CODE = 82
>>>>ADD SUBAREA RUNOFF TO MAINLINE, AT MAINLINE Tc,<<<<
>>>>(AND COMPUTE INITIAL SUBAREA RUNOFF)<
_____
INITIAL SUBAREA FLOW-LENGTH(FEET) = 210.00
ELEVATION DATA: UPSTREAM(FEET) = 75.33 DOWNSTREAM(FEET) = 70.50
Tc = K^*[(LENGTH^{**} 3.00)/(ELEVATION CHANGE)]^{**}0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 5.488
* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 5.866
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                      Ap SCS Tc
  LAND USE
              GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
                      0.12  0.40  0.100  52  5.49
COMMERCIAL
                 Α
AGRICULTURAL FAIR COVER
"PASTURE,DRYLAND" A 0.09 0.40 1.000 69 12.75
```

```
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.481
SUBAREA AREA(ACRES) = 0.20 INITIAL SUBAREA RUNOFF(CFS) = 1.04
```

** ADD SUBAREA RUNOFF TO MAINLINE AT MAINLINE Tc:

MAINLINE Tc(MIN.) = 8.84

* 100 YEAR RAINFALL INTENSITY(INCH/HR) = 4.465

SUBAREA AREA(ACRES) = 0.20 SUBAREA RUNOFF(CFS) = 0.78

EFFECTIVE AREA(ACRES) = 1.71 AREA-AVERAGED Fm(INCH/HR) = 0.15

AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.38

TOTAL AREA(ACRES) = 1.7 PEAK FLOW RATE(CFS) = 6.64

FLOW PROCESS FROM NODE 508.00 TO NODE 509.00 IS CODE = 31

.....

>>>>COMPUTE PIPE-FLOW TRAVEL TIME THRU SUBAREA

>>>>USING COMPUTER-ESTIMATED PIPESIZE (NON-PRESSURE FLOW)<

ELEVATION DATA: UPSTREAM(FEET) = 65.20 DOWNSTREAM(FEET) = 65.00

FLOW LENGTH(FEET) = 36.00 MANNING'S N = 0.013

DEPTH OF FLOW IN 18.0 INCH PIPE IS 13.3 INCHES

PIPE-FLOW VELOCITY(FEET/SEC.) = 4.75

ESTIMATED PIPE DIAMETER(INCH) = 18.00 NUMBER OF PIPES = 1

PIPE-FLOW(CFS) = 6.64

PIPE TRAVEL TIME(MIN.) = 0.13 Tc(MIN.) = 8.96

LONGEST FLOWPATH FROM NODE 500.00 TO NODE 509.00 = 735.00 FEET.

END OF STUDY SUMMARY:

TOTAL AREA(ACRES) = 1.7 TC(MIN.) = 8.96

EFFECTIVE AREA(ACRES) = 1.71 AREA-AVERAGED Fm(INCH/HR)= 0.15

AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.377

PEAK FLOW RATE(CFS) = 6.64

** PEAK FLOW RATE TABLE **

STREAM Q To Intensity Fp(Fm) Ap Ae HEADWATER NUMBER (CFS) (MIN.) (INCH/HR) (INCH/HR) (ACRES) NODE

- 1 6.64 8.96 4.429 0.40(0.15) 0.38 1.7 500.00
- 2 6.59 9.41 4.306 0.40(0.15) 0.38 1.7 504.00

END OF RATIONAL METHOD ANALYSIS

(C) Copyright 1989-2014 Advanced Engineering Software (aes) Ver. 21.0 Release Date: 06/01/2014 License ID 1501 **********************************	******						
Problem Descriptions: SERC Drainage Study Proposed Condition South East							
*** NON-HOMOGENEOUS WATERSHED AREA-AVERAGED LOSS RATE (F AND LOW LOSS FRACTION ESTIMATIONS FOR AMC III: TOTAL 24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches)	======== m)						
SOIL-COVER AREA PERCENT OF SCS CURVE LOSS RATE TYPE (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD 1 0.64 2.00 98.(AMC II) 10.000 0.958 2 0.68 100.00 76.(AMC II) 10.000 0.836 3 0.14 100.00 70.(AMC II) 10.000 0.740 4 0.28 100.00 72.(AMC II) 10.000 0.778							
TOTAL AREA (Acres) = 1.75 AREA-AVERAGED LOSS RATE, Fm (in./hr.) = 6.410							
AREA-AVERAGED LOW LOSS FRACTION, Y = 0.137							

```
***********************************
        SMALL AREA UNIT HYDROGRAPH MODEL
______
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     Ver. 21.0 Release Date: 06/01/2014 License ID 1501
******************************
Problem Descriptions:
SERC Drainage Study
Proposed Condition
South East
 RATIONAL METHOD CALIBRATION COEFFICIENT = 0.99
 TOTAL CATCHMENT AREA(ACRES) = 1.75
 SOIL-LOSS RATE, Fm,(INCH/HR) = 6.410
 LOW LOSS FRACTION = 0.137
 TIME OF CONCENTRATION(MIN.) = 8.96
 SMALL AREA PEAK Q COMPUTED USING PEAK FLOW RATE FORMULA
 ORANGE COUNTY "VALLEY" RAINFALL VALUES ARE USED
 RETURN FREQUENCY(YEARS) = 100
  5-MINUTE POINT RAINFALL VALUE(INCHES) = 0.52
  30-MINUTE POINT RAINFALL VALUE(INCHES) = 1.09
  1-HOUR POINT RAINFALL VALUE(INCHES) = 1.45
  3-HOUR POINT RAINFALL VALUE(INCHES) = 2.43
  6-HOUR POINT RAINFALL VALUE(INCHES) = 3.36
  24-HOUR POINT RAINFALL VALUE(INCHES) = 5.63
 TOTAL CATCHMENT RUNOFF VOLUME(ACRE-FEET) = 0.70
 TOTAL CATCHMENT SOIL-LOSS VOLUME(ACRE-FEET) = 0.12
***********************
TIME VOLUME Q 0.
                      2.5 5.0 7.5 10.0
(HOURS) (AF) (CFS)
      0.0000 0.00 Q
0.02
0.17
      0.0008 0.13 Q
0.32
      0.0024 0.13 Q
0.47
      0.0041 0.13 Q
      0.0057 0.13 Q
0.62
0.77
      0.0074 0.13 Q
                   . . .
```

0.92	0.0090	0.14 Q			
1.07	0.0107	0.14 Q			
1.22	0.0124	0.14 Q			
1.37	0.0141	0.14 Q			
1.51	0.0158	0.14 Q	•		
1.66	0.0175	0.14 Q	•		
1.81	0.0192	0.14 Q			
1.96	0.0210	0.14 Q	•		
2.11	0.0227	0.14 Q	•		
2.26	0.0245	0.14 Q			
2.41	0.0263	0.14 Q			
2.56	0.0280	0.15 Q			
2.71	0.0298	0.15 Q	•		
2.86	0.0317	0.15 Q			
3.01	0.0335	0.15 Q			
3.16	0.0353	0.15 Q			
3.31	0.0372	0.15 Q			
3.46	0.0390	0.15 Q			
3.61	0.0409	0.15 Q			
3.75	0.0428	0.15 Q			
3.90	0.0447	0.16 Q			
4.05	0.0466	0.16 Q			
4.20	0.0486	0.16 Q			
4.35	0.0505	0.16 Q			
4.50	0.0525	0.16 Q			
4.65	0.0545	0.16 Q	•		
4.80	0.0565	0.16 Q	•		
4.95	0.0585	0.16 Q	•		
5.10	0.0605	0.17 Q	•		
5.25	0.0626	0.17 Q			
5.40	0.0646	0.17 Q	•		
5.55	0.0667	0.17 Q			
5.70	0.0688	0.17 Q	•		
5.85	0.0710	0.17 Q	•		
5.99	0.0731	0.17 Q			
6.14	0.0753	0.18 Q			
6.29	0.0775	0.18 Q			
6.44	0.0797	0.18 Q			
6.59	0.0819	0.18 Q			
6.74	0.0841	0.18 Q			
6.89	0.0864	0.19 Q			
7.04	0.0887	0.19 Q			
7.19	0.0910	0.19 Q			
7.34	0.0934	0.19 Q			

7.49	0.0957	0.19 Q				
7.64	0.0981	0.19 Q				
7.79	0.1005	0.20 Q	•		•	٠
7.94	0.1030	0.20 Q	•	•	•	٠
8.09	0.1055	0.20 Q	•	•	•	٠
8.23	0.1080	0.20 Q	•	٠	•	٠
8.38	0.1105	0.21 Q	•	٠	•	٠
8.53	0.1131	0.21 Q	•	٠	•	٠
8.68	0.1157	0.21 Q	٠	•	٠	٠
8.83	0.1183	0.21 Q	•	•	•	•
8.98	0.1210	0.22 Q	•	•	•	•
9.13	0.1237	0.22 Q	•	•	•	•
9.28	0.1264	0.22 Q	•	•	•	•
9.43	0.1292	0.23 Q	•	•	•	•
9.58	0.1320	0.23 Q	•	•	•	•
9.73	0.1348	0.23 Q	•	•	•	•
9.88	0.1377	0.24 Q	•	•	•	•
10.03	0.1407	0.24 Q	•	•	•	•
10.18	0.1437	0.24 Q	•	•	•	•
10.33	0.1467	0.25 Q	•	•	•	•
10.47	0.1498	0.25 .Q	•	•	•	•
10.62	0.1529	0.26 .Q	•	•	•	•
10.77	0.1561	0.26 .Q	•	•	•	•
10.92	0.1593	0.26 .Q	•	•	•	•
11.07	0.1626	0.27 .Q	•	•	•	•
11.22	0.1660	0.27 .Q	•	•	•	•
11.37	0.1694	0.28 .Q	•	•	•	•
11.52 11.67	0.1729 0.1765	0.29 .Q 0.29 .Q	•	•	•	•
11.82	0.1763	0.29 .Q 0.30 .Q	•	•	•	•
11.97	0.1801	0.30 .Q 0.31 .Q	•	•	•	•
12.12	0.1859	0.31 .Q 0.33 .Q	•	•	•	•
12.12	0.1878	0.33 .Q 0.40 .Q	•	•	•	•
12.42	0.1922	0.40 .Q 0.41 .Q	•	•	•	•
12.42	0.1972	0.41 .Q 0.42 .Q	•	•	•	•
12.71	0.2023	0.42 .Q 0.43 .Q	•	•	•	•
12.71	0.2129	0.43 .Q 0.44 .Q	•	•	•	•
13.01	0.2129	0.44 .Q 0.45 .Q	•	•	•	•
13.16	0.2184	0.45 .Q 0.46 .Q	•	•	•	•
13.31	0.2297	0.40 .Q 0.47 .Q	•	•	•	•
13.46	0.2357	0.47 .Q 0.49 .Q	•	•	•	•
13.40	0.2337	0.49 .Q 0.50 .Q	•	•	•	•
13.76	0.2418	0.50 . Q	•	•	•	•
13.70	0.2546	0.52 . Q 0.53 . Q	•	•	•	•
13.31	0.2340	0.55 . Q	•	•	•	•

14.06	0.2614	0.56	. Q				
14.21	0.2684	0.58	. Q				
14.36	0.2758	0.61	. Q				
14.51	0.2835	0.63	. Q				
14.66	0.2916	0.68	. Q				
14.81	0.3001	0.70	. Q				
14.95	0.3092	0.77	. Q				
15.10	0.3189	0.81	. Q				
15.25	0.3295	0.90	. Q				
15.40	0.3410	0.96	. Q				
15.55	0.3531	1.01	. Q				
15.70	0.3663	1.13	. Q				
15.85	0.3833	1.61	. Q				
16.00	0.4068	2.20	. Q				
16.15	0.4614	6.64			Q		
16.30	0.5105	1.32	. Q				
16.45	0.5245	0.95	. Q				
16.60	0.5356	0.85	. Q				
16.75	0.5454	0.73	. Q				
16.90	0.5540	0.66	. Q				
17.05	0.5617	0.60	. Q				
17.19	0.5687	0.55	. Q				
17.34	0.5753	0.51	. Q				
17.49	0.5814	0.48	.Q	•		•	
17.64	0.5872	0.45	.Q			•	
17.79	0.5926	0.43	.Q	•		•	
17.94	0.5979	0.41	.Q	•		•	
18.09	0.6028	0.40	.Q	•		•	
18.24	0.6072	0.30	.Q	•		•	
18.39	0.6108	0.29	.Q				
18.54	0.6143	0.28	.Q				
18.69	0.6177	0.27	.Q	•		•	
18.84	0.6209	0.26	.Q				
18.99	0.6240	0.25	Q				
19.14	0.6271	0.24	Q				
19.29	0.6300	0.23	Q				
19.43	0.6329	0.23	Q	•		•	
19.58	0.6356	0.22	Q				
19.73	0.6383	0.22	Q				
19.88	0.6410	0.21	Q				
20.03	0.6435	0.21	Q				
20.18	0.6460	0.20	-				
20.33	0.6485	0.20	Q				
20.48	0.6509	0.19	Q	•		•	

20.63	0.6532	0.19 Q	•			
20.78	0.6555	0.18 Q				
20.93	0.6578	0.18 Q				
21.08	0.6600	0.18 Q				
21.23	0.6621	0.17 Q				
21.38	0.6643	0.17 Q				
21.53	0.6664	0.17 Q				
21.67	0.6684	0.16 Q	•			
21.82	0.6704	0.16 Q				
21.97	0.6724	0.16 Q				
22.12	0.6744	0.16 Q				
22.27	0.6763	0.15 Q				
22.42	0.6782	0.15 Q			•	
22.57	0.6800	0.15 Q				
22.72	0.6819	0.15 Q	•			
22.87	0.6837	0.15 Q				
23.02	0.6855	0.14 Q				
23.17	0.6872	0.14 Q				
23.32	0.6890	0.14 Q			•	
23.47	0.6907	0.14 Q				
23.62	0.6924	0.14 Q			•	
23.77	0.6941	0.13 Q	•			
23.91	0.6957	0.13 Q				
24.06	0.6973	0.13 Q				
24.21	0.6982	0.00 Q			•	

TIME DURATION(minutes) OF PERCENTILES OF ESTIMATED PEAK FLOW RATE:

(Note: 100% of Peak Flow Rate estimate assumed to have an instantaneous time duration)

Percentile of Estimated	Duration				
Peak Flow Rate	(mir	nutes)			
=======================================	===	=======			
0%	1442.6				
10%	134.4				
20%	26.9				
30%	17.9				
40%	9.0				
50%	9.0				
60%	9.0				
70%	9.0				
80%	9.0				
90%	9.0				

Dale Avenue Subcatchment (to street) Proposed System

RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE

(Reference: 1986 ORANGE COUNTY HYDROLOGY CRITERION)

(c) Copyright 1983-2014 Advanced Engineering Software (aes)

Ver. 21.0 Release Date: 06/01/2014 License ID 1501

FILE NAME: PDALE.DAT

TIME/DATE OF STUDY: 09:31 10/10/2016

USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION:

--*TIME-OF-CONCENTRATION MODEL*--

USER SPECIFIED STORM EVENT(YEAR) = 100.00

SPECIFIED MINIMUM PIPE SIZE(INCH) = 6.00

SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE = 0.90

DATA BANK RAINFALL USED

ANTECEDENT MOISTURE CONDITION (AMC) III ASSUMED FOR RATIONAL METHOD

USER-DEFINED STREET-SECTIONS FOR COUPLED PIPEFLOW AND STREETFLOW MODEL
HALF- CROWN TO STREET-CROSSFALL: CURB GUTTER-GEOMETRIES: MANNING
WIDTH CROSSFALL IN- / OUT-/PARK- HEIGHT WIDTH LIP HIKE FACTOR

NO. (FT) (FT) SIDE / SIDE / WAY (FT) (FT) (FT) (FT)

1 30.0 20.0 0.018/0.018/0.020 0.67 2.00 0.0313 0.167 0.0150

GLOBAL STREET FLOW-DEPTH CONSTRAINTS:

- 1. Relative Flow-Depth = 0.00 FEET as (Maximum Allowable Street Flow Depth) (Top-of-Curb)
- 2. (Depth)*(Velocity) Constraint = 6.0 (FT*FT/S)
- *SIZE PIPE WITH A FLOW CAPACITY GREATER THAN

OR EQUAL TO THE UPSTREAM TRIBUTARY PIPE.*

*USER-SPECIFIED MINIMUM TOPOGRAPHIC SLOPE ADJUSTMENT NOT SELECTED

FLOW PROCESS FROM NODE 400.00 TO NODE 401.00 IS CODE = 21

>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<

>>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<<

```
INITIAL SUBAREA FLOW-LENGTH(FEET) = 26.00
ELEVATION DATA: UPSTREAM(FEET) = 73.70 DOWNSTREAM(FEET) = 72.20
Tc = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]**0.20
SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) = 5.000
 * 100 YEAR RAINFALL INTENSITY(INCH/HR) = 6.187
SUBAREA Tc AND LOSS RATE DATA(AMC III):
 DEVELOPMENT TYPE/ SCS SOIL AREA Fp
                                       Ap SCS Tc
   LAND USE
               GROUP (ACRES) (INCH/HR) (DECIMAL) CN (MIN.)
COMMERCIAL
                      URBAN GOOD COVER
 "TURF"
                   0.03 0.40 1.000 53 5.00
SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) = 0.40
SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap = 0.533
SUBAREA RUNOFF(CFS) = 0.28
TOTAL AREA(ACRES) = 0.05 PEAK FLOW RATE(CFS) = 0.28
______
END OF STUDY SUMMARY:
TOTAL AREA(ACRES) = 0.1 \text{ TC(MIN.)} = 5.00
EFFECTIVE AREA(ACRES) = 0.05 AREA-AVERAGED Fm(INCH/HR)= 0.21
AREA-AVERAGED Fp(INCH/HR) = 0.40 AREA-AVERAGED Ap = 0.533
PEAK FLOW RATE(CFS) = 0.28
```

END OF RATIONAL METHOD ANALYSIS

NO	N-HOMOGENEOUS WATERSHED AREA-AVERAGED LOSS RATE (Fm) AND LOW LOSS FRACTION ESTIMATIONS

Problem	Descriptions:
SERC Dra	ainage Study
Propose	d Condition
Dale	
AND LC	DW LOSS FRACTION ESTIMATIONS FOR AMC III:
TOTAL	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) OVER AREA PERCENT OF SCS CURVE LOSS RATE
TOTAL SOIL-CO	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) OVER AREA PERCENT OF SCS CURVE LOSS RATE (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD
TOTAL	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) OVER AREA PERCENT OF SCS CURVE LOSS RATE
TOTAL SOIL-CO TYPE 1 2	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) OVER AREA PERCENT OF SCS CURVE LOSS RATE (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD 0.03 2.00 98.(AMC II) 10.000 0.958
TOTAL SOIL-CO TYPE 1 2 TOTAL	24-HOUR DURATION RAINFALL DEPTH = 5.63 (inches) OVER AREA PERCENT OF SCS CURVE LOSS RATE (Acres) PERVIOUS AREA NUMBER Fp(in./hr.) YIELD 0.03 2.00 98.(AMC II) 10.000 0.958 0.03 100.00 39.(AMC II) 10.000 0.285

RATIONAL METHOD CALIBRATION COEFFICIENT = 1.38

TOTAL CATCHMENT AREA(ACRES) = 0.05

SOIL-LOSS RATE, Fm,(INCH/HR) = 4.912

LOW LOSS FRACTION = 0.365

TIME OF CONCENTRATION(MIN.) = 5.00

SMALL AREA PEAK Q COMPUTED USING PEAK FLOW RATE FORMULA

ORANGE COUNTY "VALLEY" RAINFALL VALUES ARE USED

RETURN FREQUENCY(YEARS) = 100

5-MINUTE POINT RAINFALL VALUE(INCHES) = 0.52

30-MINUTE POINT RAINFALL VALUE(INCHES) = 1.09

1-HOUR POINT RAINFALL VALUE(INCHES) = 1.45

3-HOUR POINT RAINFALL VALUE(INCHES) = 2.43

6-HOUR POINT RAINFALL VALUE(INCHES) = 3.36

24-HOUR POINT RAINFALL VALUE(INCHES) = 5.63

TOTAL CATCHMENT RUNOFF VOLUME(ACRE-FEET) = 0.02 TOTAL CATCHMENT SOIL-LOSS VOLUME(ACRE-FEET) = 0.00

	-	0.	2.5		5.0	7.5	10.0
0.0000	0.00	Q					
0.0000	0.00	Q					
0.0001	0.00	Q					
0.0001	0.00	Q					
0.0001	0.00	Q					
0.0002	0.00	Q					
0.0002	0.00	Q					
0.0002	0.00	Q					
0.0002	0.00	Q					
0.0003	0.00	Q					
0.0003	0.00	Q					
0.0003	0.00	Q					
0.0004	0.00	Q					
0.0004	0.00	Q					
0.0004	0.00	Q					
0.0004	0.00	Q					
0.0005	0.00	Q					
	0.0000 0.0000 0.0001 0.0001 0.0002 0.0002 0.0002 0.0002 0.0003 0.0003 0.0003 0.0004 0.0004 0.0004	0.0000 0.00 0.0000 0.00 0.0001 0.00 0.0001 0.00 0.0001 0.00 0.0002 0.00 0.0002 0.00 0.0002 0.00 0.0002 0.00 0.0003 0.00 0.0003 0.00 0.0003 0.00 0.0004 0.00 0.0004 0.00 0.0004 0.00 0.0004 0.00	0.0000 0.00 Q 0.0000 0.00 Q 0.0001 0.00 Q 0.0001 0.00 Q 0.0001 0.00 Q 0.0002 0.00 Q 0.0002 0.00 Q 0.0002 0.00 Q 0.0002 0.00 Q 0.0002 0.00 Q 0.0003 0.00 Q 0.0003 0.00 Q 0.0003 0.00 Q 0.0004 0.00 Q 0.0004 0.00 Q 0.0004 0.00 Q	0.0000 0.00 Q . 0.0000 0.00 Q . 0.0000 0.00 Q . 0.0001 0.00 Q . 0.0001 0.00 Q . 0.0002 0.00 Q . 0.0003 0.00 Q . 0.0003 0.00 Q . 0.0003 0.00 Q . 0.0004 0.00 Q . 0.0004 0.00 Q . 0.0004 0.00 Q .	0.0000 0.00 Q	0.0000	0.0000

1.50	0.0005	0.00 Q			
1.58	0.0005	0.00 Q			
1.67	0.0006	0.00 Q			
1.75	0.0006	0.00 Q			
1.83	0.0006	0.00 Q		•	
1.92	0.0006	0.00 Q		•	
2.00	0.0007	0.00 Q			
2.08	0.0007	0.00 Q		•	
2.17	0.0007	0.00 Q		•	
2.25	0.0008	0.00 Q			
2.33	0.0008	0.00 Q			
2.42	0.0008	0.00 Q			
2.50	0.0009	0.00 Q			
2.58	0.0009	0.00 Q			
2.67	0.0009	0.00 Q		•	
2.75	0.0009	0.00 Q			
2.83	0.0010	0.00 Q		•	
2.92	0.0010	0.00 Q		•	
3.00	0.0010	0.00 Q		•	
3.08	0.0011	0.00 Q		•	
3.17	0.0011	0.00 Q			
3.25	0.0011	0.00 Q		•	
3.33	0.0012	0.00 Q		•	
3.42	0.0012	0.00 Q			
3.50	0.0012	0.00 Q		•	
3.58	0.0013	0.00 Q		•	
3.67	0.0013	0.00 Q			
3.75	0.0013	0.00 Q			
3.83	0.0014	0.00 Q			
3.92	0.0014	0.00 Q			
4.00	0.0014	0.00 Q			
4.08	0.0015	0.00 Q		•	
4.17	0.0015	0.00 Q		•	
4.25	0.0015	0.00 Q			
4.33	0.0016	0.00 Q			
4.42	0.0016	0.00 Q	•		
4.50	0.0016	0.00 Q			
4.58	0.0017	0.00 Q			
4.67	0.0017	0.00 Q			
4.75	0.0017	0.00 Q			
4.83	0.0018	0.00 Q			
4.92	0.0018	0.01 Q			
5.00	0.0018	0.01 Q		•	
5.08	0.0019	0.01 Q			

5.17	0.0019	0.01 Q	•			
5.25	0.0019	0.01 Q	•			
5.33	0.0020	0.01 Q	•			
5.42	0.0020	0.01 Q				•
5.50	0.0020	0.01 Q		•		•
5.58	0.0021	0.01 Q				•
5.67	0.0021	0.01 Q				•
5.75	0.0021	0.01 Q	•	•	•	•
5.83	0.0022	0.01 Q				•
5.92	0.0022	0.01 Q	•	•		•
6.00	0.0023	0.01 Q	•	•	•	•
6.08	0.0023	0.01 Q	•	•	•	•
6.17	0.0023	0.01 Q	•	•	•	•
6.25	0.0024	0.01 Q				•
6.33	0.0024	0.01 Q	•			
6.42	0.0024	0.01 Q	•			
6.50	0.0025	0.01 Q			•	
6.58	0.0025	0.01 Q	•	•		
6.67	0.0026	0.01 Q		•		
6.75	0.0026	0.01 Q			•	
6.83	0.0026	0.01 Q	•	•		
6.92	0.0027	0.01 Q	•	•		
7.00	0.0027	0.01 Q	•			
7.08	0.0027	0.01 Q	•	•		
7.17	0.0028	0.01 Q	•	•		
7.25	0.0028	0.01 Q	•	•		
7.33	0.0029	0.01 Q	•	•		
7.42	0.0029	0.01 Q			•	
7.50	0.0029	0.01 Q			•	
7.58	0.0030	0.01 Q			•	
7.67	0.0030	0.01 Q	•	•		
7.75	0.0031	0.01 Q	•	•		
7.83	0.0031	0.01 Q	•	•		
7.92	0.0032	0.01 Q	•	•		
8.00	0.0032	0.01 Q	•	•		
8.08	0.0032	0.01 Q	•	•		
8.17	0.0033	0.01 Q	•	•		
8.25	0.0033	0.01 Q	•	•		
8.33	0.0034	0.01 Q	•			
8.42	0.0034	0.01 Q		•		
8.50	0.0035	0.01 Q	•	•		
8.58	0.0035	0.01 Q	•	•		
8.67	0.0035	0.01 Q				
8.75	0.0036	0.01 Q				

8.83	0.0036	0.01 Q		•		
8.92	0.0037	0.01 Q	•	•		
9.00	0.0037	0.01 Q	•	•		
9.08	0.0038	0.01 Q	•	•		
9.17	0.0038	0.01 Q				
9.25	0.0039	0.01 Q			•	
9.33	0.0039	0.01 Q				
9.42	0.0040	0.01 Q				
9.50	0.0040	0.01 Q	•		•	
9.58	0.0041	0.01 Q	•			
9.67	0.0041	0.01 Q	•	•		
9.75	0.0042	0.01 Q	•	•		
9.83	0.0042	0.01 Q	•		•	
9.92	0.0042	0.01 Q	•	•		
10.00	0.0043	0.01 Q				
10.08	0.0044	0.01 Q	•			
10.17	0.0044	0.01 Q				
10.25	0.0045	0.01 Q				
10.33	0.0045	0.01 Q				
10.42	0.0046	0.01 Q				
10.50	0.0046	0.01 Q				
10.58	0.0047	0.01 Q				
10.67	0.0047	0.01 Q				
10.75	0.0048	0.01 Q				
10.83	0.0048	0.01 Q				
10.92	0.0049	0.01 Q				
11.00	0.0049	0.01 Q				
11.08	0.0050	0.01 Q				
11.17	0.0051	0.01 Q				
11.25	0.0051	0.01 Q				
11.33	0.0052	0.01 Q				
11.42	0.0052	0.01 Q				
11.50	0.0053	0.01 Q				
11.58	0.0054	0.01 Q				
11.67	0.0054	0.01 Q		•		
11.75	0.0055	0.01 Q	•			
11.83	0.0055	0.01 Q		•		
11.92	0.0056	0.01 Q				
12.00	0.0057	0.01 Q				
12.08	0.0057	0.01 Q				
12.17	0.0058	0.01 Q				
12.25	0.0059	0.01 Q				
12.33	0.0060	0.01 Q	•	•		
12.42	0.0061	0.01 Q	•	•		
		•				

12.50	0.0062	0.01 Q	•	•		
12.58	0.0063	0.01 Q	•	•		
12.67	0.0063	0.01 Q				
12.75	0.0064	0.01 Q				
12.83	0.0065	0.01 Q	•			
12.92	0.0066	0.01 Q	•			
13.00	0.0067	0.01 Q	•			
13.08	0.0068	0.01 Q	•	•	•	
13.17	0.0069	0.01 Q	•			
13.25	0.0070	0.01 Q	•	•	•	
13.33	0.0071	0.01 Q	•	•	•	
13.42	0.0072	0.01 Q	•	•	•	
13.50	0.0073	0.02 Q	•	•	•	
13.58	0.0074	0.02 Q	•	•	•	
13.67	0.0075	0.02 Q	•	•	•	
13.75	0.0076	0.02 Q	•			
13.83	0.0077	0.02 Q				
13.92	0.0079	0.02 Q				
14.00	0.0080	0.02 Q	•			
14.08	0.0081	0.02 Q	•	•		
14.17	0.0082	0.02 Q	•			
14.25	0.0083	0.02 Q	•	•	•	
14.33	0.0085	0.02 Q	•	•	•	
14.42	0.0086	0.02 Q	•	•		
14.50	0.0087	0.02 Q				
14.58	0.0089	0.02 Q	•	•		
14.67	0.0090	0.02 Q	•	•		
14.75	0.0092	0.02 Q	•	•		
14.83	0.0093	0.02 Q	•			
14.92	0.0095	0.02 Q				
15.00	0.0096	0.02 Q	•			
15.08	0.0098	0.03 Q	•			
15.17	0.0100	0.03 Q				
15.25	0.0102	0.03 Q	•	•		
15.33	0.0104	0.03 Q	•			
15.42	0.0106	0.03 Q	•			
15.50	0.0108	0.03 Q	•			
15.58	0.0110	0.03 Q	•	•	•	
15.67	0.0112	0.04 Q				
15.75	0.0115	0.04 Q	•	•	•	
15.83	0.0118	0.05 Q	•	•		
15.92	0.0122	0.07 Q	•	•		
16.00	0.0128	0.09 Q				
16.08	0.0141	0.28 .Q	•			

16.17	0.0152	0.06	Q				
16.25	0.0156	0.04	Q				
16.33	0.0158	0.03	Q				
16.42	0.0160	0.03	Q			•	
16.50	0.0162	0.03	Q				•
16.58	0.0164	0.02	Q				•
16.67	0.0166	0.02	Q				•
16.75	0.0167	0.02	Q				
16.83	0.0169	0.02	Q				
16.92	0.0170	0.02	Q				
17.00	0.0171	0.02	Q			•	
17.08	0.0173	0.02	Q				
17.17	0.0174	0.02	Q			•	
17.25	0.0175	0.02	-				
17.33	0.0176	0.02	Q			•	
17.42	0.0177	0.01	Q				
17.50	0.0178	0.01	Q			•	
17.58	0.0179	0.01	Q			•	
17.67	0.0180	0.01	Q				
17.75	0.0181	0.01	Q			•	
17.83	0.0182	0.01	Q			•	
17.92	0.0182	0.01	Q			•	
18.00	0.0183	0.01	Q				
18.08	0.0184	0.01	Q			•	
18.17	0.0185	0.01	Q				
18.25	0.0185	0.01	Q				
18.33	0.0186	0.01	Q			•	
18.42	0.0187	0.01	Q		•		
18.50	0.0187	0.01	Q			•	
18.58	0.0188	0.01	Q			•	
18.67	0.0188	0.01	Q			•	
18.75	0.0189	0.01	Q		•		
18.83	0.0189	0.01	Q				
18.92	0.0190	0.01	Q			•	
19.00	0.0190	0.01	Q				
19.08	0.0191	0.01	Q				
19.17	0.0191	0.01	Q			•	
19.25	0.0192	0.01	Q		•		•
19.33	0.0192	0.01	Q	•		•	
19.42	0.0193	0.01	Q	•		•	
19.50	0.0193	0.01	Q			•	
19.58	0.0194	0.01	Q			•	
19.67	0.0194	0.01	Q			•	•
19.75	0.0195	0.01	Q				

19.83	0.0195	0.01	Q			
19.92	0.0196	0.01	Q			
20.00	0.0196	0.01	Q			
20.08	0.0196	0.01	Q			
20.17	0.0197	0.01	Q			
20.25	0.0197	0.01	Q			
20.33	0.0198	0.01	Q			
20.42	0.0198	0.01	Q			
20.50	0.0199	0.01	Q			
20.58	0.0199	0.01	Q		•	
20.67	0.0199	0.01	Q	•	•	
20.75	0.0200	0.01	Q	•	•	
20.83	0.0200	0.01	Q			
20.92	0.0200	0.01	Q	•	•	
21.00	0.0201	0.01	Q	•	•	
21.08	0.0201	0.01	Q			
21.17	0.0202	0.01	Q			
21.25	0.0202	0.01	Q			
21.33	0.0202	0.01	Q			
21.42	0.0203	0.01	Q			
21.50	0.0203	0.01	Q			
21.58	0.0203	0.01	Q			
21.67	0.0204	0.00	Q			
21.75	0.0204	0.00	Q			
21.83	0.0204	0.00	Q			
21.92	0.0205	0.00	Q			
22.00	0.0205	0.00	Q			
22.08	0.0205	0.00	Q			
22.17	0.0206	0.00	Q			
22.25	0.0206	0.00	Q			
22.33	0.0206	0.00	Q			
22.42	0.0207	0.00	Q			
22.50	0.0207	0.00	Q			
22.58	0.0207	0.00	Q			
22.67	0.0208	0.00	Q			
22.75	0.0208	0.00	Q			
22.83	0.0208	0.00	Q			
22.92	0.0209	0.00	Q			
23.00	0.0209	0.00	Q			
23.08	0.0209	0.00	Q			
23.17	0.0209	0.00	Q		•	
23.25	0.0210	0.00	Q		•	
23.33	0.0210	0.00	Q			
23.42	0.0210	0.00	Q			

23.50	0.0211	0.00 Q			
23.58	0.0211	0.00 Q			
23.67	0.0211	0.00 Q			
23.75	0.0211	0.00 Q			
23.83	0.0212	0.00 Q			
23.92	0.0212	0.00 Q			
24.00	0.0212	0.00 Q			
24.08	0.0212	0.00 Q			

TIME DURATION(minutes) OF PERCENTILES OF ESTIMATED PEAK FLOW RATE:

(Note: 100% of Peak Flow Rate estimate assumed to have an instantaneous time duration)

Percentile of Estimated	Duration	
Peak Flow Rate	(minutes)	
=======================================	====	=====
0%	1440.0	
10%	65.0	
20%	15.0	
30%	10.0	
40%	5.0	
50%	5.0	
60%	5.0	
70%	5.0	
80%	5.0	
90%	5.0	



<u>APPENDIX I</u>

9.8.2.3.2 Recommendations for Dimensioning Circular Pump Stations

9.8.2.3.2.2 Floor Clearance - Cf

0.3Db < Cf < 0.5Db

9.8.2.3.2.3 Wall Clearance - Cw

Cw > 0.25Db > 100mm

9.8.2.3.2.4 Inlet Bell Clearance - Cb

Cb > 0.25Db > 100mm

9.8.2.3.2.5 Sump Diameter - Ds

 2 Pumps Centreline
 2 Pumps Offset by <= 0.5Db</td>

 Ds > 2Db + 2Cw + Cb
 Ds > 2.5Db + 2Cw + Cb

 3 Pumps Centreline
 3 Pumps Offset by <= 0.5Db</td>

 Ds > 3Db + 2Cw + 2Cb
 Ds > 5Db + 2Cw + 2Cb

9.8.2.3.2.6 Inlet Bell Diameter - Db

Submersible and other pumps Pumps without volute in wet pit

Use Volute Diameter

Use Inlet Bell Diameter

Db shall be chosen in accordance with constraints outlined in section 9.8.6

9.8.2.3.2.7 Inflow Pipe

Elevation of inflow pipe(s) should not be greater than the minimum liquid level Inflow pipe(s) should be positioned radially and normal to the pumps

For the last five pipe diameters before entering the sump, the inflow pipe(s) shall be $\frac{1}{2} \left(\frac{1}{2} \right) = \frac{1}{2} \left(\frac{1}{2} \right) \left(\frac{1$

straight and have no valves or fittings

9.8.6 Inlet Bell Design Diameter

Db should be chosen to satisfy the following constraints on the Inlet Bell Velocity

For: 315 L/s < Q < 1260 L/s For: Q < 315 L/s 0.9 m/s < V < 2.4 m/s 0.9 m/s < V < 2.7 m/s

9.8.7 Required Submergence for Minimising Surface Vortices

S should be at least that given by the following equation

S/Db = 1.0 + 2.3F

S = submergence above horizontal inlet plane or centreline of vertical inlet

F = Froude number = V/sqrt(gDb)

9.8.3.3 Circular Plan Wet Pit for Solids-Bearing

Wet pit design should adhere to 9.8.2.3

Wet pit shall have sloped surfaces around the inlet bells or pumps

Removal of floating solids can be accomplished by lowering the submergence level sufficiently (0.5Db to 1.0Db) to create a strong surface vortex. Pumping under these

conditions should be limited to brief, infrequent periods.

Q (cfs)	6.64	Q (L/s)	188.0239	MAX			
Db (inches)	12.0	Db (mm)	304.8				
		A (m2)	0.072966	•			
		V (m/s)	2.577	> 0.9 m/s	but < 2.7 r	m/s	
		g (m2/s)	9.81				
		F	1.490223	-			
S (inches)	54.0	S (mm)	1371.6	>	1350	mm	
Cf (inches)	4.0	Cf (mm)	101.6	>	91.44	mm but <	152.4
Cw (inches)	4.0	Cw (mm)	101.6	>	100	mm	
Cb (inches)	4.0	Cb (mm)	101.6	>	100	mm	
Ds (inches)	77.0	Ds (mm)	1955.8	>	1930.4	mm	

Invert of Well: 61.3

9.2 ft Deep (from Rim)6.4 ft Wide (Diameter)

298 ft3 Total Volume

2230 Gallons



APPENDIX J

ORANGE COUNTY HYDROLOGY MANUAL

A. J. Nestlinger, Civil Engineer
RCE #33815 Expires June 30, 1990

Reviewed By

R. D. Runge, Chief, Section Engineer
RCE #28580 Expires March 31, 1990

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ORANGE COUNTY ENVIRONMENTAL MANAGEMENT AGENCY M. STORM, DIRECTOR

PREFACE

The County of Orange Hydrology Manual was prepared under a contract (D85-078) with Williamson and Schmid, Irvine, California, approved by the Orange County Board of Supervisors on June 18, 1985.

Prepared by

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RCE #29281 Expires March 31, 1987

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RCE #12261 Expires March 31, 1989

WILLIAMSON AND SCHMID, CIVIL ENGINEERS, IRVINE, CALIFORNIA
OCTOBER 1986

AUTHOR'S ACKNOWLEDGEMENTS

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Key contributors to the project effort include Tim J. Durbin, MS, RCE, for his work in the stream gage analysis and adjustment for urbanization; Bob Whitley, Ph.D. for his statistical evaluation of the stream gage data confidence levels and the coupling of modeling uncertainty; and Joe DeVries, Ph.D., RCE for his work on the channel routing studies and certainty of results.

Particular acknowledgements are paid to the Los Angeles District Corps of Engineers (COE); Chief of Hydrologic Engineering Section, Andy Sienkiewich; and Chief, Hydrologic Engineering Unit 1, John Pedersen, for their generous cooperation and time.

Other acknowledgements are paid to the several engineering firms and governmental agencies who have contributed time through the course of four drainage committees over the last 5 years, or through the attendance of the public presentations, or through the review of this manuscript.

Finally, acknowledgements are paid to the several engineers who have contributed to the development of this Hydrology Manual. Special acknowledgements are paid to Alan J. Nestlinger, BSAP, MPA, RCE who has been closely involved with Agency hydrology studies and the subsequent manual since 1967. Several sections of this manual were authored or coauthored by Alan. Special acknowledgments are also paid to the many key Agency staff members including (alphabetically) Joe Natsuhara, BS, RCE, Carl Nelson, MSCE, RCE, Dick Runge, BS, RCE and Jim Williams, MSCE, RCE.

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SECTION A

INTRODUCTION

A.I. PURPOSE

This manual provides the computational techniques and criteria for the estimation of runoff, discharges, and volumes for use in submittals to the Orange County Environmental Management Agency (hereinafter "Agency").

A.2. HYDROLOGIC PROTECTION LEVELS

It is the goal of the Agency to provide 100-year return frequency flood protection for all habitable structures and other non-floodproof structures. Consequently, all drainage plans must demonstrate this 100-year flood protection criteria.

Additionally, it is the design objective of the Agency to afford specific design criteria for the more frequent flood events. That is, flood protection levels for 10- and 25-year floods may be required for major street travelways, catch basin sump design, and other conditions. The design criteria may be obtained from the Agency.

For additional related information see Appendices 1.1 and 1.2.

A.3. PRESENTATION

Precipitation and loss information used in the Rational Method and the Unit Hydrograph procedure for developing flowrates are contained in Sections B and C, respectively. Specific guidelines for application of the Rational Method are contained in Section D. Section E contains the procedures for developing runoff hydrographs using the Unit Hydrograph method and

Sections F through I contain guidelines for application of various flood routing methods. The development of runoff hydrographs for small areas is discussed in Section J and watershed medeling guidelines are provided in Section K. Peak flowrate curves for areas where use of single area unit hydrographs are appropriate are contained in Section L. The appendices provide additional discussion on various hydrology topics.

SECTION B

PRECIPITATION

B.I. PRECIPITATION DEPTH-DURATION-FREQUENCY

The following definitions of precipitation depth, duration, and frequency are used:

<u>Precipitation depth</u>: the amount of precipitation occurring during a specified duration of storm time. Precipitation depth is usually expressed in units of inches.

<u>Duration</u>: the specified length of storm time under study. Duration may be expressed in any time unit such as seconds, minutes, hours, days or season.

<u>Frequency</u>: the frequency of occurrence of events with the specified precipitation depth and duration. This is expressed in terms of either the return period or exceedance probability, both of which are defined below.

<u>Intensity-duration</u>: dividing precipitation depth by duration, an average intensity for a specified duration is obtained.

<u>Critical duration</u>: the critical duration of a design storm event for a hydraulic structure is usually the "time of concentration," which is the time for water deposited at the most remote part of a watershed to flow to the structure, outlet or spillway.

Exceedance (cumulative) probability: the probability that a precipitation event of a specified depth and duration will be exceeded in one year.

Return period (recurrence interval): the long term average number of years between occurrences of an event of a given depth and duration, either equaled or exceeded.

The exceedance probability (p) and return period (T) are related by

$$p = 1/T$$

A 100-year precipitation event will not necessarily occur exactly once in every 100 years but actually has a finite probability that it will occur in several consecutive years or not at all in a period of 100 years.

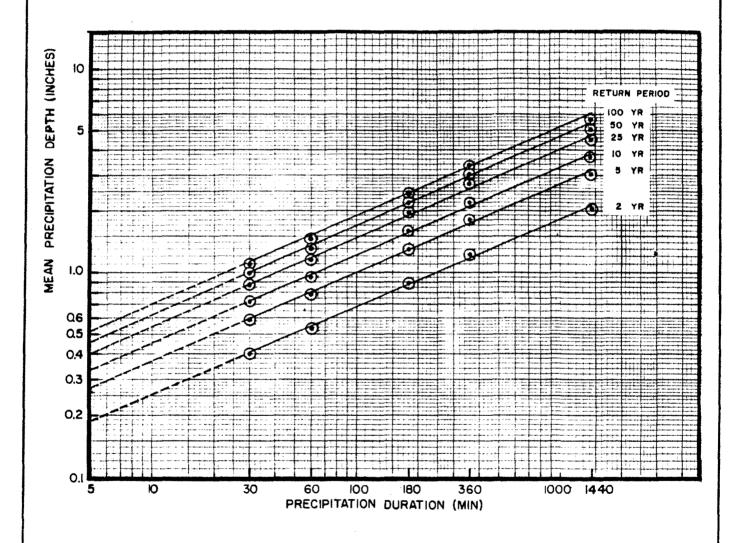
B.2. POINT PRECIPITATION

The depth-duration relationships for the non-mountainous areas of Orange County (i.e., elevations less than about 2,000 feet) are generalized into the logarithmic plots shown in Figure B-1. These design point precipitation plots are appropriate for design hydrology studies. Included in the figure are regression equations which relate mean precipitation depths to precipitation duration. For mountainous areas, the State of California DWR data for rain gage station 156 (Santiago Peak) shall be used (see Figure B-2).

Table B.1. contains the Long Duration-Depth-Frequency values for non-mountainous and mountainous watersheds.

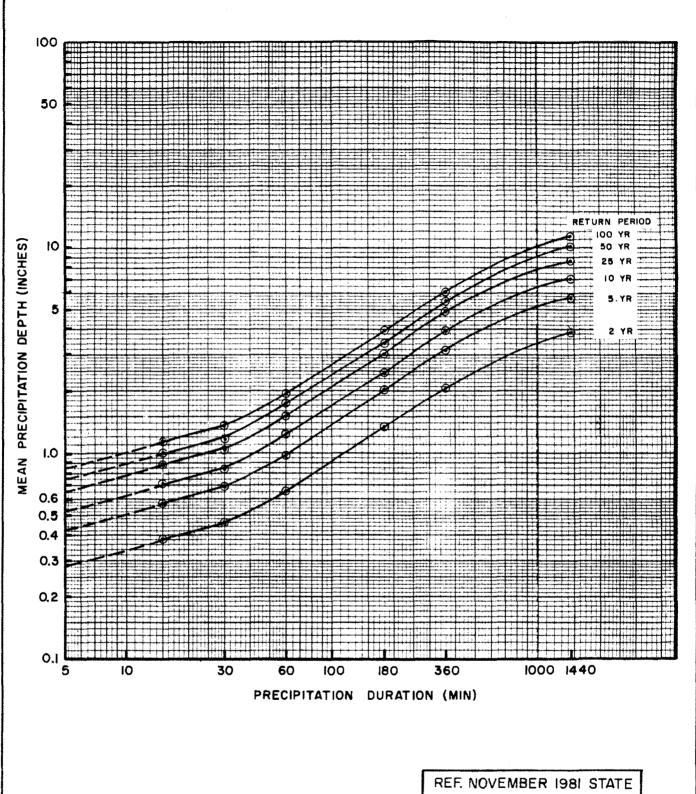
Regression Equations: D(t) = at^b
(D= Depth in inches, t= duration in minutes)

a	<u>b</u>
0.095	0.426
0.131	0.438
0.170	0.427
0.200	0.434
0.225	0.434
0.259	0.427
	0.095 0.131 0.170 0.200 0.225



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MEAN PRECIPITATION
DEPTHS FOR
NONMOUNTAINOUS AREAS



REF. NOVEMBER 1981 STATE OF CALIF DWR SANTIAGO PEAK #RC156

ORANGE COUNTY
HYDROLOGY MANUAL

MEAN PRECIPITATION
DEPTHS FOR
MOUNTAINOUS AREA

TABLE B.1.

MAXIMUM PRECIPITATION FOR INDICATED DURATION D-DAYS (INCHES)

BELOW 2000' ELEVATION

Return Period													
In Yrs.	<u> 1D</u>	<u>2D</u>	<u>3D</u>	4D	<u>5D</u>	<u>6D</u>	<u>8D</u>	<u> 10D</u>	<u>15D</u>	<u> 20D</u>	<u>30D</u>	60D	365D
2	2.05	2.76	3.08	3.21	3.36	3.61	3.94	4.24	4.73	5.21	6.20	8.44	13.60
5	3.03	4.24	4.79	5.01	5.23	5.59	6.05	6.47	7.20	7.83	9.18	12.69	19.13
10	3.68	5.23	5.92	6.22	6.50	6.94	7.44	7.94	8.79	9.49	11.07	15.48	22.56
20	4.31	6.17	6.99	7.38	7.71	8.22	8.74	9.31	10.26	11.02	12.80	18.08	25.69
25	4.49	6.46	7.33	7.75	8.09	8.63	9.15	9.74	10.72	11.49	13.34	18.90	26.66
40	4.89	7.06	8.03	8.50	8.88	9.47	9.98	10.62	10.95	12.46	14.44	20.58	28.63
50	5.07	7.35	8.35	8.86	9.25	9.86	10.38	11.03	12.11	12.91	14.95	21.37	29.55
100	5.63	8.22	9.35	9.95	10.38	11.07	11.57	12.29	13.45	14.28	16.51	23.77	32.32

ABOVE 2000' ELEVATION

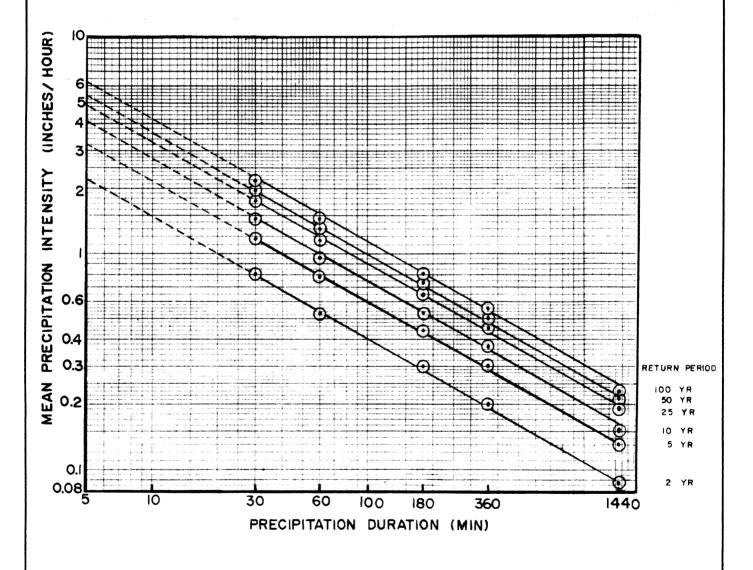
Return Period In Yrs.	10	20	3D	4D	5D	6D	8D	10D	15D	20D	30D	60D	365D
2	3.81	5.33	5.89	6.22	6.66	7.17	7.88	8.38	8.97	9.62	11.29	15.91	26.05
5	5.71	8.25	9.23	9.75	10.40	11.12	12.17	12.81	13.72	14.51	16.73	23.74	36.88
10	7.05	10.26	11.58	12.23	12.98	13.80	15.02	15.71	16.83	17.66	20.17	28.69	43.86
20	8.36	12.20	13.85	14.63	15.45	16.35	17.72	18.42	19.74	20.59	23.33	33.25	50.33
25	8.76	12.81	14.58	15.40	16.24	17.16	18.57	19.27	20.65	21.50	24.31	34.66	52.35
40	9.62	14.08	16.08	16.99	17.87	18.82	20.32	21.02	22.53	21.95	26.32	37.56	53.33
50	10.02	14.68	16.79	17.74	18.63	19.61	21.14	21.84	23.41	24.25	27.25	38.91	58.43
100	11.27	16.52	18.98	20.05	20.99	22.01	23.65	24.33	26.09	26.91	30.09	42.99	64.30

B.3. RATIONAL METHOD PRECIPITATION INTENSITY CURVES

For determining peak discharge by the rational method, which is presented in Section D, precipitation intensity rather than depth is an input value in the calculation. To obtain a plot of intensity versus duration, the curves in Figures B-1 and B-2 are converted by dividing precipitation depth by duration. The non-mountainous area precipitation intensity curves are presented in Figure B-3 and can be used for the rational method analysis of drainage areas below 2000 feet in elevation. For drainage areas above 2000 feet, the mountainous area precipitation intensity curves in Figure B-4 can be used.

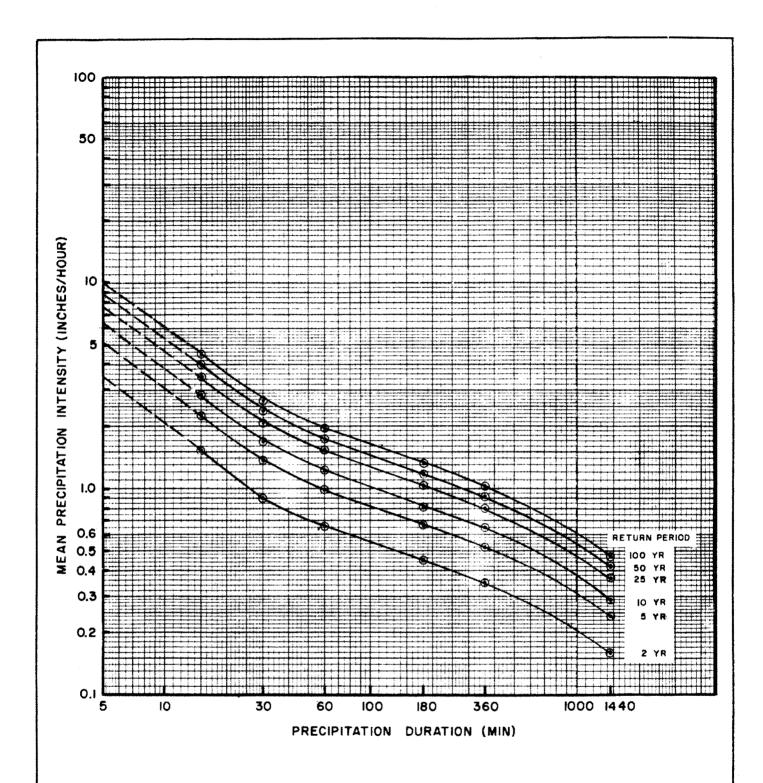
Regression Equations: I(t) = at^b
(I= Intensity in inches/hour, t= duration in minutes)

Return Frequency (years)	a	b
2	5.702	-0.574
5	7.870	-0.562
10	10.209	-0.573
25	11.995	-0.566
50	13.521	-0.566
100	15.560	-0.573



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MEAN PRECIPITATION INTENSITIES FOR NONMOUNTAINOUS AREAS



ORANGE COUNTY HYDROLOGY MANUAL MEAN PRECIPITATION INTENSITIES FOR MOUNTAINOUS AREA

B.4. UNIT HYDROGRAPH METHOD DESIGN STORM

The Orange County desgin storm shall be used for all unit hydrograph method calculations (Figures B-5a, b, c).

The point precipitation depths in Table B.2 shall be used for the single-day design storm.

For watersheds with detention basins, a multi-day storm shall be used as shown in Sections B.5 and B.6.

Due to the variations in point precipitation values between mountainous and nonmountainous areas, area averaging of rainfall is required when catchments include areas both above and below the 2,000-foot elevation.

TABLE B.2.
ORANGE COUNTY POINT PRECIPITATION DATA (inches)

DURATION

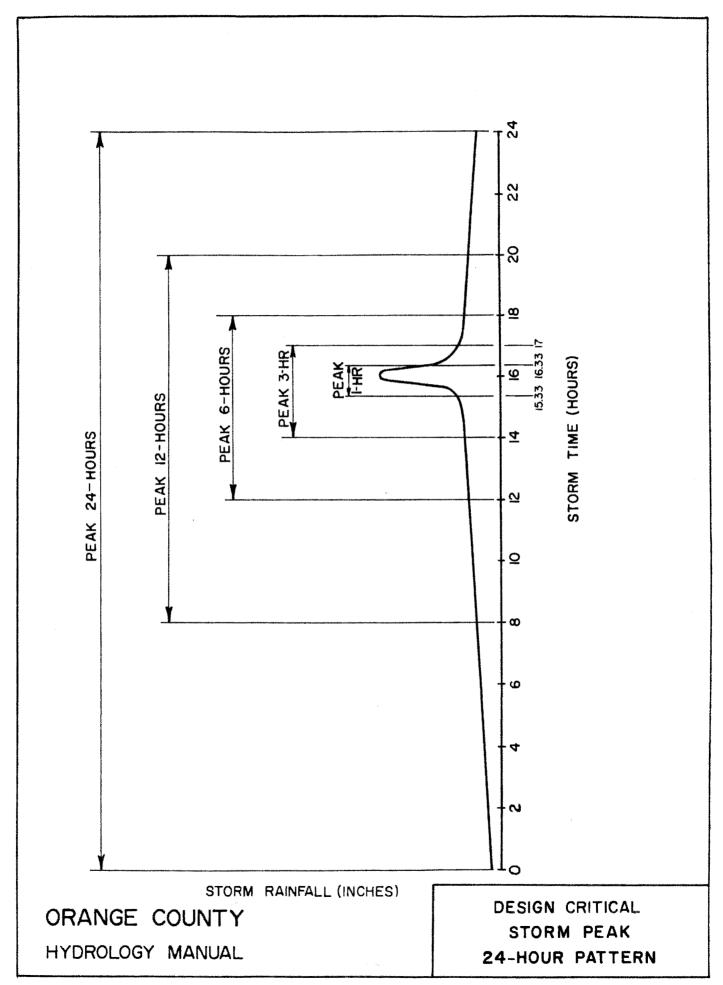
11 3H T-YR. 5M 30M 6H 24H 100 0.52(.78) 1.09(1.34) 1.45(1.94) 2.43(3.96) 3.36(6.19) 5.63(11.27) 1.30(1.73) 50 0.45(.71) 0.98(1.19)2.19(3.52) 3.02(5.51) 5.07(10.02) 25 0.40(.63) 0.87(1.04)1.15(1.51) 1.94(3.08) 2.71(4.81) 4.49(8.76) 10 0.34(.50) 0.72(.84)0.95(1.22) 1.59(2.48) 2.20(3.87) 3.68(7.05) 5 0.26(.40) 0.59(.68) 0.78(.99) 1.31(2.01) 1.81(3.14) 3.03(5.71) 2 0.19(.26) 0.40(.45) 0.53(.66) 0.89(1.34) 1.22(2.09) 2.05(3.81)

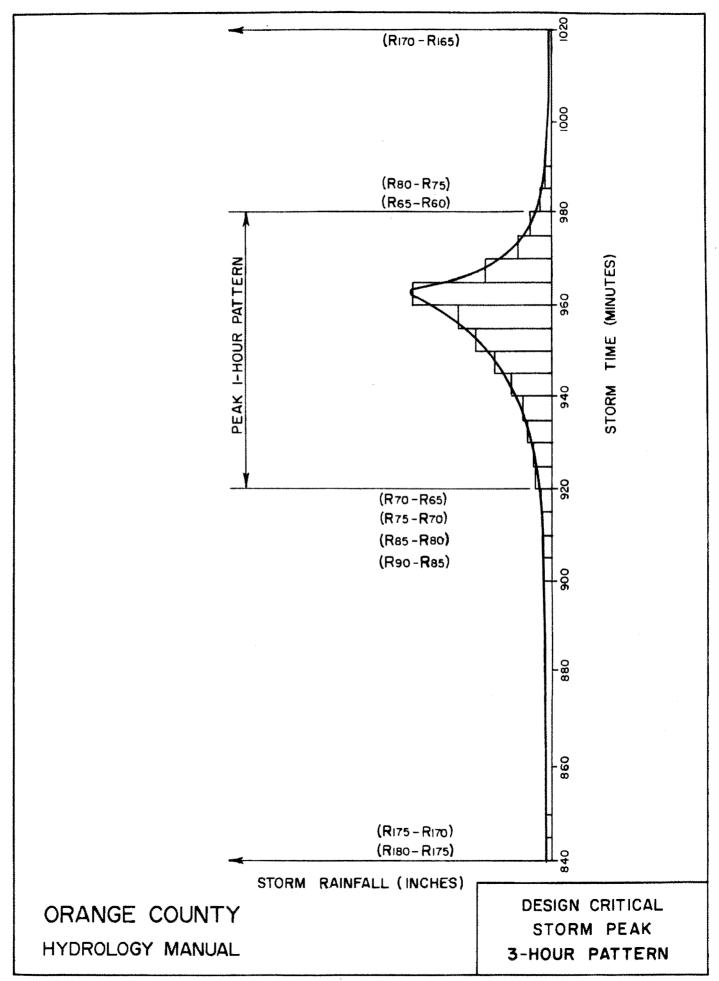
NOTES:

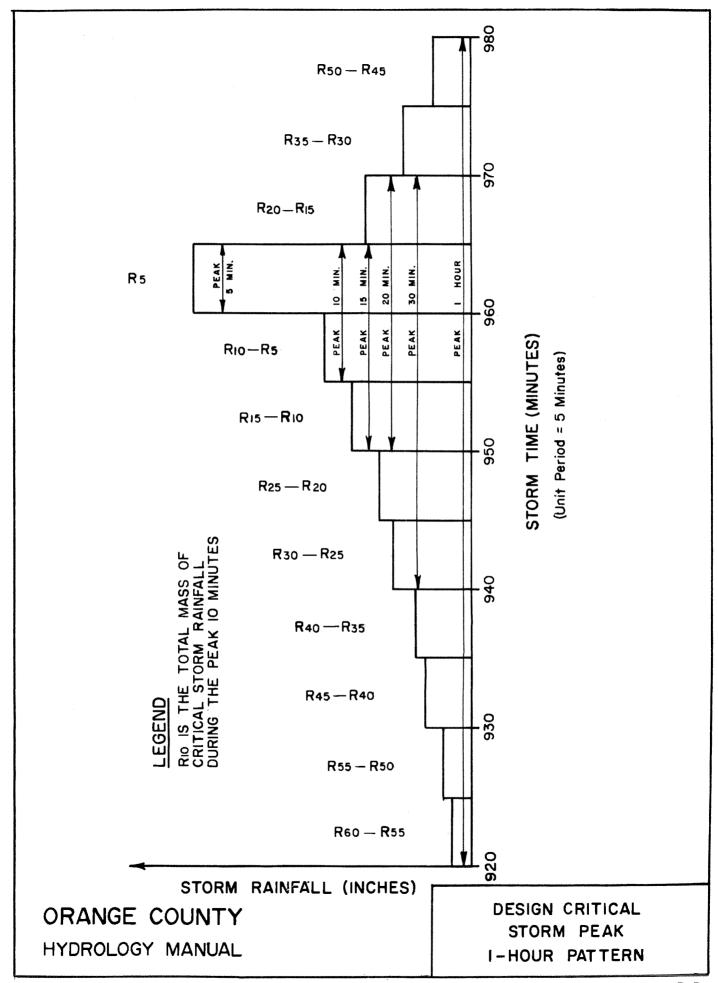
- (1.) Numbers in () are from the Santiago Peak gage station #156, DWR depth-duration-frequency table (1983). Use in areas above 2,000 feet in elevation.
- (2.) Precipitation data for nonmountainous areas taken from an average of 25 rain gages (see ref. 7). Use in areas below 2,000 feet in elevation.
- (3.) All 5M values are extrapolations (see ref. 7).
- (4.) M = minutes; H = hours.

Because the average rainfall intensity for a single storm event tends to decrease with respect to increased area, the point precipitation values in Table B.2 shall be reduced by the factors shown in Figure B-6. The catchment area shall be the total drainage area contributing runoff to the point of concentration where the design discharge is being calculated. For example, at a confluence, in order to provide peak discharges for the two tributaries and the downstream channel, three different sets of reduction factors are required: a separate analysis for each of the two tributaries, and another analysis for the summed area of the two tributaries at the confluence point.

After the point precipitation depths have been reduced based on Figure B-6, precipitation depths for each unit time interval (usually 5 minutes) can be determined graphically using Figure B-7. This procedure is demonstrated in the sample problem of Section E. After calculation of the unit time interval precipitation depths, the depths are arranged into the storm pattern shown in Figures B-5 a, b, c so that the peak unit interval occurs at two-thirds of the storm duration.







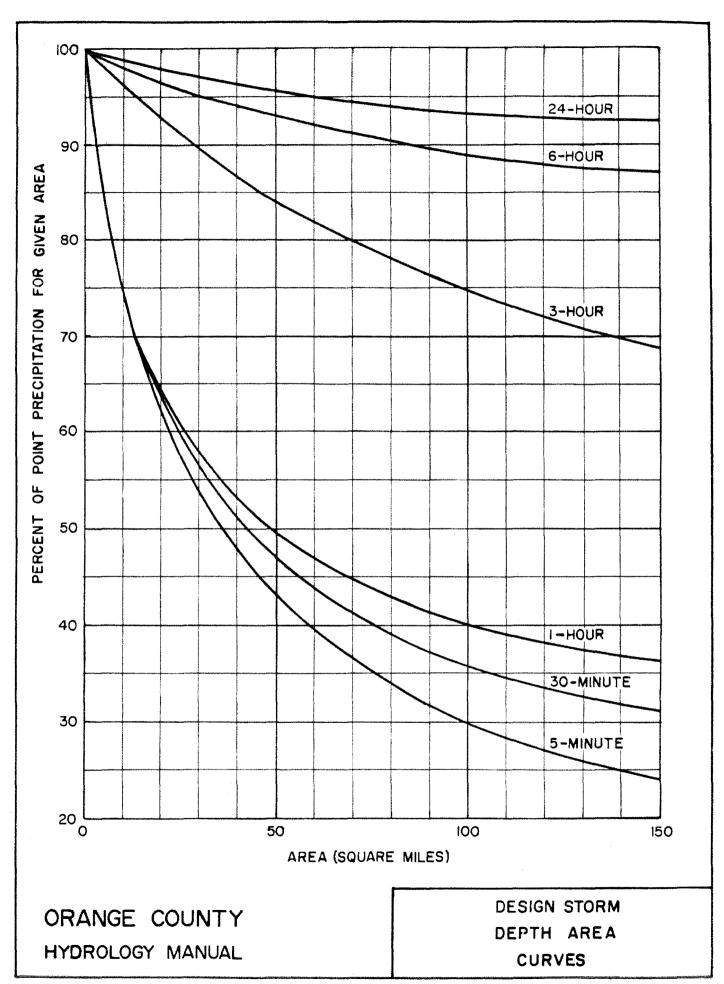
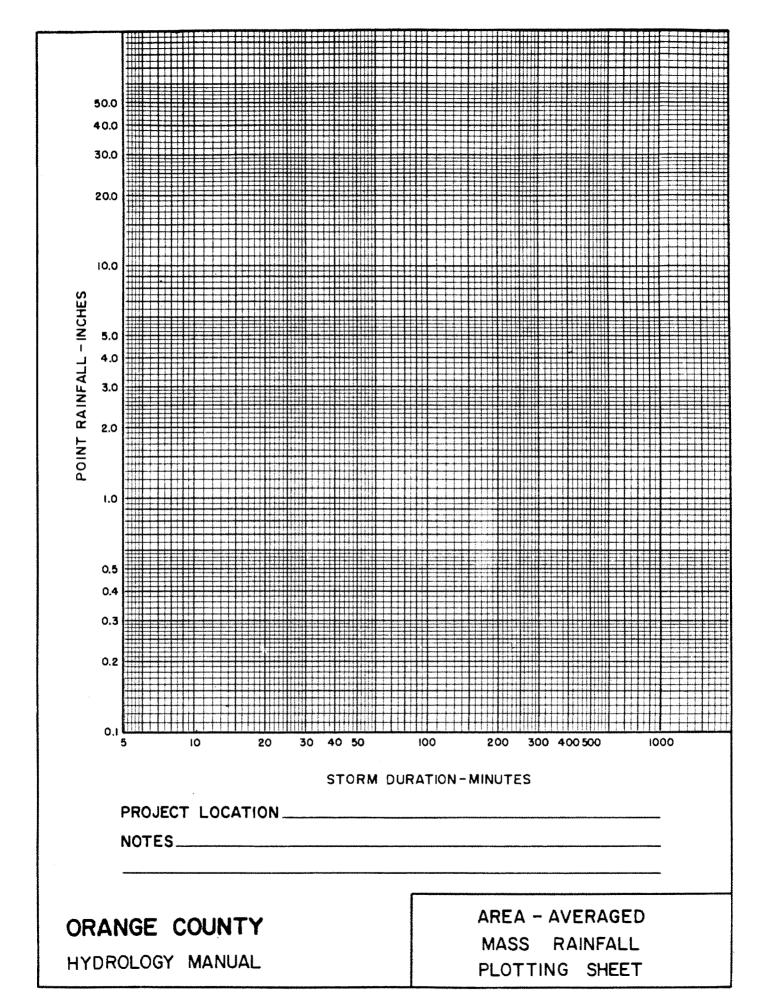


Figure B-6



B - 15

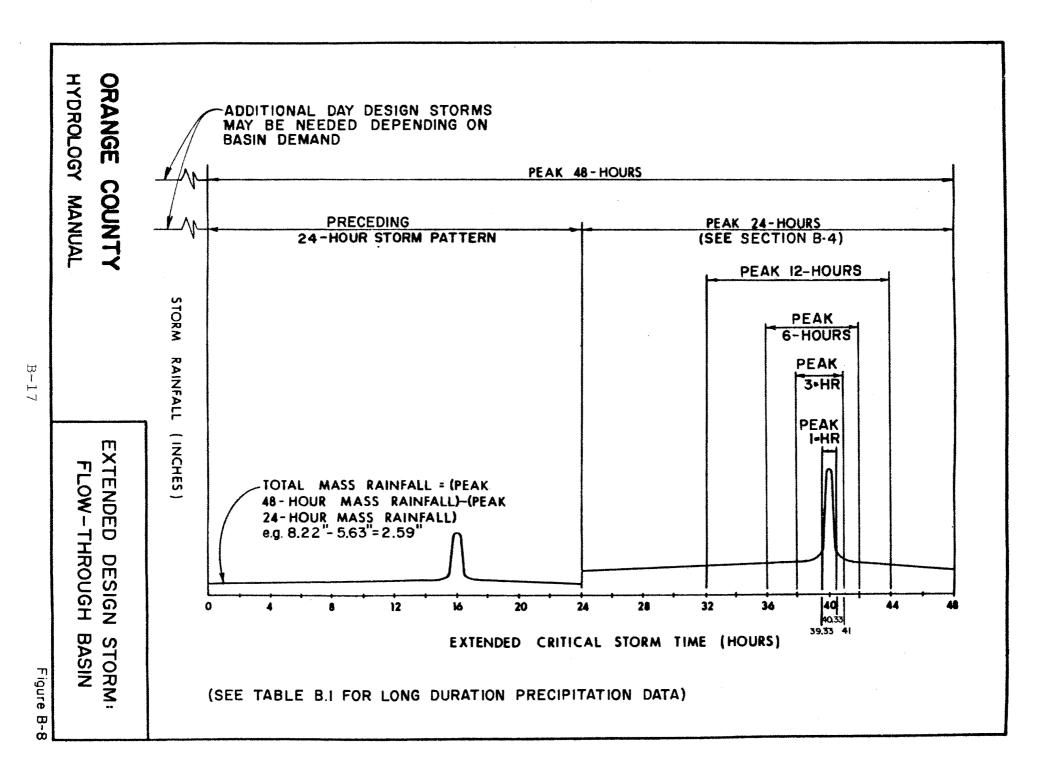
B.5. DESIGN STORM FOR WATERSHEDS WITH FLOW-THROUGH DETENTION BASINS

Due to the interaction of watershed size, Tc, percentage of peak discharge reduction, and basin volume, the critical storm duration is generally not known (in advance) for a watershed flood control system which includes one or several detention basins. Hence, the use of the 24-hour design storm may not be the "critical" storm for flow-through detention basin design purposes, and a longer duration design storm may be needed. Figure B-8 illustrates the extended design storm (multiday) for a two day duration. Longer duration design storms are developed in a similar fashion.

The multiday design storm utilizes the structure of Figure B-8 for all flow-through detention basin systems. Successive day storms are developed and added in the front of the previously developed design storm patterns until the detention basin system demonstrates no increase in the required basin volume due to the further extension of the design storm pattern. By increasing the basin outlet capacity, the critical duration can be reduced.

From Figure B-8 it is seen that the extended design storm is constructed from an arrangement of rainfalls of identical T-year return frequency. That is, even though a two day or longer duration multiday storm is being used to test the detention basin's level of flood protection, the extended design storm still contains no more than T-year rainfall depths for the extended duration. Each of the 24-hour storm patterns are constructed by a simple scaling of the peak 24-hour design pattern according to a ratio of the respective 24-hour precipitation values.

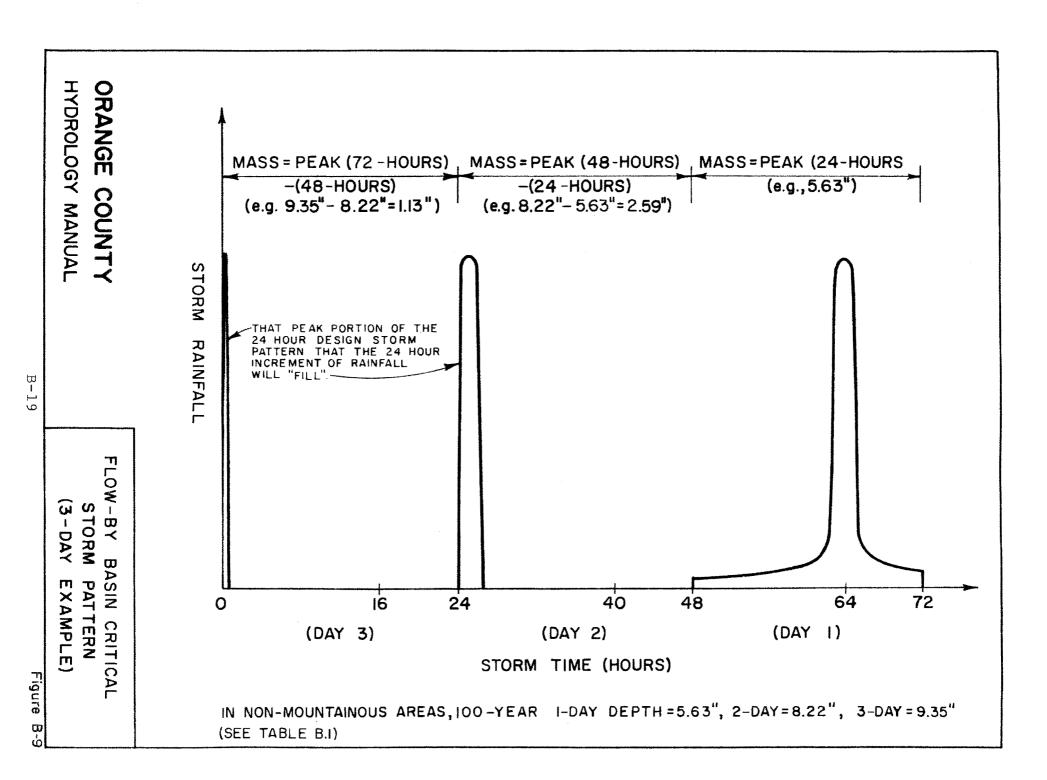
The point precipitation values for durations longer than one day may be taken from Table B.1.



The multi-day design storm shall be reduced based on the Depth-Area Reduction curves shown in Figure B-6. As in the case of a watershed with no detention basins, the reduction area shall be the total drainage area contributing runoff to the point of concentration where the design discharge is being calculated. However, if a reduction area of a storm applied to the area downstream of the basin produces a higher discharge than the storm applied to the entire watershed, the Agency will require flood control facility design based on the higher discharge.

B.6. DESIGN STORM FOR WATERSHEDS WITH FLOW-BY DETENTION BASINS

For many of the same reasons cited in Section B.5, a single day storm may not be the critical storm for a flow-by basin. A slightly different multiday storm configuration as shown in Figure B-9 shall be used for watersheds with flow-by basins. Point precipitation values from Tables B.1 and B.2 shall be used. The Depth-Area Reduction Curves (Figure B-6) shall be applied in the same manner as descibed in Section B.5.



SECTION C

LOSSES

C.I. WATERSHED LOSSES

Watershed outflow is a function of precipitation, watershed losses, and routing processes. Watershed routing processes are presented in Sections D and E where the rational and unit hydrograph methods are presented in detail. Precipitation estimation procedures and data are presented in Section B. This section will present watershed loss computation methods and data.

Watershed losses are considered to be depression storage, vegetation interception and transpiration, minor amounts of evaporation, and infiltration. Infiltration is the process of water entering the soil surface and percolating downward into the soil where it is stored during a precipitation event. Subsequently, the stored soil water may be consumptively used by vegetation, percolate further downward to groundwater storage, or exit the soil surface as seeps or springs. Seepage from stream bank storage is the primary source of baseflow which is derived from prior precipitation events. When making estimates of stormwater runoff it is assumed that infiltration is a loss for the storm event under consideration. For purposes of the hydrologic methods used in this manual, infiltration is expressed as a rate in inches per hour (refs. 2, 9, 10).

C.2. HYDROLOGIC SOIL GROUPS

The major factor affecting infiltration is the nature of the soil itself. The soil surface characteristics, its ability to transmit water to subsurface layers and total storage capacity are all major factors in the infiltration capabilities of a particular soil. Soils are classified into four hydrologic soil groups as follows (refs. 2, 3):

GROUP A: Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well-drained sands or gravels. These soils have a high rate of water transmission.

GROUP B: Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained sandy-loam soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

GROUP C: Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of silty-loam soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

GROUP D: High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

C.2.1. Infiltration Rates

Soil infiltration rates have been estimated for each of the soil groups by laboratory studies and measurements. These measurements show that an initially dry soil will have an associated infiltration rate which essentially decreases with time as the soil becomes wetted. As the soil is subjected to continual rainfall, this infiltration rate approaches a minimum infiltration rate which represents the percolation rate of the saturated soil.

C.2.2. Soil Maps

Maps have been prepared which designate the locations of the various soil groups within the County of Orange (see Figure C-I) and are contained in the pocket in the back of this manual.

C.3. SOIL COVER AND HYDROLOGIC CONDITIONS

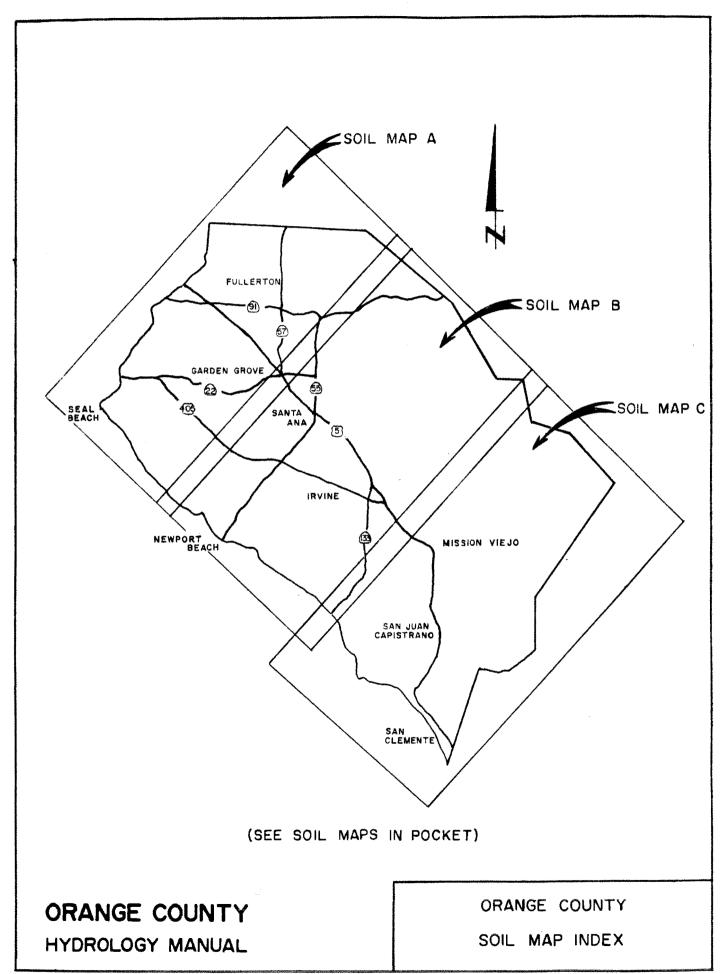
The type of vegetation or ground cover on a watershed, and the quality or density of that cover, have a major impact on the infiltration capacity of a given soil. Definitions of specific cover types are provided in Figure C-2. Further refinement in the cover type descriptions is provided by the definition of cover quality as follows:

POOR: Heavily grazed or regularly burned areas. Less than 50 percent of the ground surface is protected by plant cover or brush and tree canopy.

FAIR: Moderate cover with 50 percent to 75 percent of the ground surface protected by vegetation.

GOOD: Heavy or dense cover with more than 75 percent of the ground surface protected by vegetation.

In most cases, watershed existing conditions cover type and quality can be readily determined by a field review of a watershed. In ultimate planned open spaces, the soil cover condition shall be considered as "good." Curve Number (CN) is one measure of runoff potential for a particular soil group and cover complex conditions. Figure C-3 provides the CN values for various types and quality of ground cover. Impervious areas shall be assigned a CN of 98. It is noted that for ultimately developed conditions, the CN for urban landscaping (turf) is provided in Figure C-3.



Residential Landscaping (Lawn, Shrubs, etc.) - The pervious portions of commercial establishments, single and multiple family dwellings, trailer parks and schools where the predominant land cover is lawn, shrubbery and trees.

Row Crops - Lettuce, tomatoes, beets, tulips or any field crop planted in rows far enough apart that most of the soil surface is exposed to rainfall impact throughout the growing season. At plowing, planting and harvest times it is equivalent to fallow.

<u>Small Grain</u> - Wheat, oats, barley, flax, etc. planted in rows close enough that the soil surface is not exposed except during planting and shortly thereafter.

<u>Legumes</u> - Alfalfa, sweetclover, timothy, etc. and combinations are either planted in close rows or broadcast.

Fallow - Fallow land is land plowed but not yet seeded or tilled.

Woodland - grass - Areas with an open cover of broadleaf or coniferous trees usually live oak and pines, with the intervening ground space occupied by annual grasses or weeds. The trees may occur singly or in small clumps. Canopy density, the amount of ground surface shaded at high noon, is from 20 to 50 percent.

<u>Woodland</u> - Areas on which coniferous or broadleaf trees predominate. The canopy density is at least 50 percent. Open areas may have a cover of annual or perennial grasses or of brush. Herbaceous plant cover under the trees is usually sparse because of leaf or needle litter accumulation.

Chaparral - Land on which the principal vegetation consists of evergreen shrubs with broad, hard, stiff leaves such as manzonita, ceanothus and scrub oak. The brush cover is usually dense or moderately dense. Diffusely branched evergreen shrubs with fine needle-like leaves, such as chamise and redchank, with dense high growth are also included in this soil cover.

Annual Grass - Land on which the principal vegetation consists of annual grasses and weeds such as annual bromes, wild barley, soft chess, ryegrass and filaree.

<u>Irrigated Pasture</u> - Irrigated land planted to perennial grasses and legumes for production of forage and which is cultivated only to establish or renew the stand of plants. Dry land pasture is considered as annual grass.

<u>Meadow</u> - Land areas with seasonally high water table, locally called cienegas. Principal vegetation consists of sod-forming grasses interspersed with other plants.

Orchard (Deciduous) - Land planted to such deciduous trees as apples, apricots, pears, walnuts, and almonds.

Orchard (Evergreen) - Land planted to evergreen trees which include citrus and avocados and coniferous plantings.

<u>Turf</u> - Golf courses, parks and similar lands where the predominant cover is irrigated mowed close-grown turf grass. Parks in which trees are dense may be classified as woodland.

ORANGE COUNTY HYDROLOGY MANUAL

SOIL COVER
TYPE DEFINITIONS

·- as	Quality of Cover (2) A		Soil Group		
Cover Type (3)			В	С	
NATURAL COVERS -					
Barren (Rockland, eroded and graded land)		78	86	91	
Chaparral, Broadleaf (Manzonita, ceanothus and scrub oak)	Poor	53	70	80	
	Fair	40	63	75	
	Good	31	57	71	
Chaparral, Narrowleaf (Chamise and redshank)	Poor	71	82	88	
	Fair	55	72	81	
Grass, Annual or Perennial	Poor	67	78	86	
	Fair	50	69	79	
	Good	38	61	74	
Meadows or Cienegas (Areas with seasonally high water table, principal vegetation is sod forming grass)	Poor	63	77	85	
	Fair	51	70	80	
	Good	30	58	71	
Open Brush (Soft wood shrubs - buckwheat, sage, etc.)	Poor	62	76	84	
	Fair	46	66	77	
	Good	41	63	75	
Woodland (Coniferous or broadleaf trees predominate. Canopy density is at least 50 percent.)	Poor	45	66	77	
	Fair	36	60	73	
	Good	25	55	70	
Woodland, Grass (Coniferous or broadleaf trees with canopy density from 20 to 50 percent)	Poor	57	73	82	
	Fair	44	65	77	
	Good	33	58	72	
URBAN COVERS -					
Residential or Commercial Landscaping (Lawn, shrubs, etc.)	Good	32	56	69	
Turf (Irrigated and mowed grass)	Poor	58	74	83	
	Fair	44	65	77	
	Good	33	58	72	
AGRICULTURAL COVERS -					
Fallow (Land plowed but not tilled or seeded)		77	86	91	

ORANGE COUNTY
HYDROLOGY MANUAL

CURVE NUMBERS
FOR
PERVIOUS AREAS

Curve Numbers of Hydrologic Soil-Cover Complexes For Pervious Areas-AMC II						
	Quality of Soil Gr			Group		
Cover Type (3)	Cover (2)		В	C	D	
AGRICULTURAL COVERS (Continued)						
Legumes, Close Seeded (Alfalfa, sweetclover, timothy, etc.)	Poor Good	66 58	77 72	85 81	89 85	
Orchards, Evergreen (Citrus, avocados, etc.)	Poor Fair Good	57 44 33	73 65 58	82 77 72	86 82 79	
Pasture, Dryland (Annual grasses)	Poor Fair Good	68 49 39	79 69 61	86 79 74	89 84 80	
Pasture, Irrigated (Legumes and perennial grass)	Poor Fair Good	58 44 33	74 65 58	83 77 72	37 82 79	
Row Crops (Field crops - tomatoes, sugar beets, etc.)	Poor Good	72 67	81 78	88 85	91 89	
Small grain (Wheat, oats, barley, etc.)	Poor Good	65 63	76 75	84 83	83 87	

Notes:

- 1. All curve numbers are for Antecedent Moisture Condition (AMC) II.
- 2. Quality of cover definitions:

Poor-Heavily grazed, regularly burned areas, or areas of high burn potential. Less than 50 percent of the ground surface is protected by plant cover or brush and tree canopy.

Fair-Moderate cover with 50 percent to 75 percent of the ground surface protected.

Good-Heavy or dense cover with more than 75 percent of the ground surface protected.

- 3. See figure C-2 for definition of cover types.
- 4. Impervious areas are assigned curve number 98.

ORANGE COUNTY HYDROLOGY MANUAL FOR PERVIOUS AREAS

C.4. WATERSHED DEVELOPMENT CONDITIONS

Ultimate development of the watershed should normally be assumed since watershed urbanization is reasonably likely within the expected life of most hydraulic facilities. Long range master plans for the County and incorporated cities should be reviewed to insure that reasonable land use assumptions are made for the ultimate development of the watershed. A field review shall also be made to confirm existing use and drainage patterns. Particular attention shall be paid to existing and proposed landscape practices, as it is common in some areas to use ornamental gravels underlain by impervious plastic materials in place of lawns and shrubs. Appropriate actual impervious percentages can then be selected from Figure C-4. It should be noted that the recommended values from these figures are for average conditions and, therefore, some adjustment for particular applications may be required.

C.5. ANTECEDENT MOISTURE CONDITION (AMC)

The definitions for the AMC classifications are:

AMC I: Lowest runoff potential. The watershed soils are dry enough to allow satisfactory grading or cultivation to take place.

AMC II: Moderate runoff potential; an average study condition.

AMC III: Highest runoff potential. The watershed is practically saturated from antecedent rains. Heavy rainfall or light rainfall and low temperatures have occurred within the last five days.

In the rainfall based hydrology methods it is normally assumed that a low AMC index (high loss rates) will be used in developing short return period storms (2-5 years), and a moderate to high AMC index (low loss rates) will be used in developing longer return period storms (10-100 year). For the

ACTUAL IMPERVIOUS COVER

Land Use (1)	Range-Percent	Recommended Value For Average Conditions-Percent (2)
Natural or Agriculture	0 - 0	0
Public Park	10 - 25	15
School	30 - 50	40
Single Family Residential: (3)		
2.5 acre lots 1 acre lots 2 dwellings/acre 3-4 dwellings/acre 5-7 dwellings/acre 8-10 dwellings/acre More than 10 dwellings/acre	5 - 15 10 - 25 20 - 40 30 - 50 35 - 55 50 - 70 65 - 90	10 20 30 40 50 60 80
Condominiums	45 - 70	65
Apartments	65 - 90	80
Mobile Home Park	60 - 85	75
Commercial, Downtown Business or Industrial	80 - 100	90

Notes:

- 1. Land use should be based on ultimate development of the watershed. Long range master plans for the County and incorporated cities should be reviewed to insure reasonable land use assumptions.
- 2. Recommended values are based on average conditions which may not apply to a particular study area. The percentage impervious may vary greatly even on comparable sized lots due to differences in dwelling size, improvements, etc. Landscape practices should also be considered as it is common in some areas to use ornamental gravels underlain by impervious plastic materials in place of lawns and shrubs. A field investigation of a study area shall always be made, and a review of aerial photos, where available, may assist in estimating the percentage of impervious cover in developed areas.
- 3. For typical equestrian subdivisions increase impervious area 5 percent over the values recommended in the table above.

ORANGE COUNTY
HYDROLOGY MANUAL

FOR
DEVELOPED AREAS

purposes of design hydrology, AMC I will be used for the 2- and 5-year storm events. The watershed condition AMC II will be used for the 10-, 25-, and 50-year return frequency storms. For the case of the 100-year return frequency design storm, AMC III will be used.

C.5.1. Adjustment of Curve Numbers (CN) for AMC

The CN values selected for a particular soil cover type and quality also depend upon the AMC condition assumed. The CN values listed in Figure C-3 correspond to AMC II and require adjustment in order to represent either AMC I or AMC III. Table C-I provides the necessary CN adjustments to account for AMC.

TABLE C.1. CURVE NUMBER RELATIONSHIPS

CN for AMC	Corresponding CN	for AMC Condition
Condition II		III
100	100	100
95	87	99
90	78	98
85	70	97
80	63	94
75	57	91
70	51	87
65	45	83
60	40	79
55	35	75
50	31	70
45	27	65
40	23	60
35	19	55
30	15	50
25	12	45
20	9	39
15	7	33
10	4	26
5	2	17
0	0	0

C.6. ESTIMATION OF LOSS RATES

In estimating infiltration rates for design hydrology, a watershed curve number (CN) is determined for each soil-cover complex within the watershed using Figure C-3. The CN scale has a range of 0 to 98, where a low CN indicates low runoff potential (high infiltration), and a high CN indicates high runoff potential (low infiltration). Selection of a CN takes into account the major factors affecting infiltration on pervious surfaces including the hydrologic soil group, cover type and quality, and antecedent moisture condition (AMC).

Also included in the CN selection are the effects of "initial abstraction" (Ia) which represents the combined effects of other effective rainfall losses including depression storage, vegetation interception, evaporation, and transpiration, among other factors.

C.6.1. Estimation of Initial Abstraction (Ia)

The initial abstraction (Ia) for an area is a function of land use, treatment, and condition; interception; infiltration; depression storage; and antecedent soil moisture. An estimate for Ia is given by the SCS as

$$Ia = 0.25$$
 (C.1)

where S is an estimate of total soil capacity given by

$$S = \frac{1000}{CN} - 10 \tag{C.2}$$

where CN is the area curve number.

C.6.2. Estimation of Storm Runoff Yield

Given the CN for a subarea A_j , the corresponding 24-hour storm runoff yield fraction, Y_i , is estimated by

$$Y_{j} = \frac{(P_{24} - Ia)^{2}}{(P_{24} - Ia + S)P_{24}}$$
 (C.3)

where

Y_j = 24-hour storm runoff yield fraction for

subarea Aj

 $P_{24} = 24$ -hour storm rainfall

Ia = initial abstraction from (C.1)

S = see(C.2)

It is noted that should labe greater than P_{24} in (C.3), then Y_j is defined to be zero. In this manual, the notation Y and Y_j will represent the yield fraction rather than the volume of runoff.

If the area under study contains several (say m) CN designations, then the yield, Y, for the total area must represent the net effect of the several curve numbers. By weighting each of the subarea yield values according to the respective areas,

$$Y = (Y_1A_1 + \cdots + Y_mA_m)/(A_1 + A_2 + \cdots + A_m)$$
 (C.4) where each Y_i follows from (C.3).

C.6.3. Low Loss Rate, F*

In design storm runoff hydrograph studies, the following formula is used to estimate that portion of rainfall to be attributed to watershed losses:

$$\overline{Y} = 1 - Y$$
 (C.5)

where

 \overline{Y} = catchment low loss fraction

Y = catchment 24-hour storm runoff yield fraction computed from (C.4)

Using the low loss fraction, \overline{Y} , the corresponding low loss rate, F*, is given by

$$F^* = \overline{Y} \cdot I \tag{C.6}$$

where I is the rainfall intensity and F* has units of inches/hour.

C.6.4. Estimation of Maximum Loss Rates for Pervious Areas, Fp

Table C.2 lists the maximum loss rates (inch/hour), F_p , for pervious area as a function of soil group.

TABLE C.2. MAXIMUM EFFECTIVE PERVIOUS AREA LOSS RATES (inch/hour), $F_{\rm D}$

SOIL GROUP:	<u>A</u>	8	C	<u>D</u>
F _p :	0.40	0.30	0.25	0.20

Table C.2 reflects the model calibration assuming an F_p of 0.30 in/hr. for all the considered catchments and storm return frequencies. This mean value of F_p of 0.30 in/hr. was assigned to Hydrologic Soil Group B due to the actual average soil conditions in the reconstitution study areas. The F_p values for Hydrologic Soil Groups A, C, and D, were assigned to account for the different soil types that may be found in Orange County.

C.6.5. Estimation of Catchment Maximum Loss Rates, Fm

The maximum loss rate selected from Table C.2 applies to the pervious area fraction of the watershed. The loss rate assumed for an impervious surface is 0.0 inch/hour. The maximum loss rate, $F_{\rm m}$, for a catchment is therefore given by

$$F_{m} = a_{p}F_{p} \tag{C.7}$$

where a_p is the pervious area fraction and F_p is the maximum loss rate for the pervious area (Section C.6.4).

Should a catchment contain several F_m values, the composite F_m value is determined as a simple area average of the several F_m values.

C.6.6. Design Storm Loss Rates

In design storm runoff hydrograph studies, a 24-hour duration storm pattern is used to develop the time distribution of effective rainfall over the watershed. The effective rainfall quantities are determined by subtracting the watershed losses from the design storm rainfall.

The loss rate used for a particular catchment is a combination of the maximum loss rate F_m and the low loss rate F^* . F^* is used as the loss rate unless F^* exceeds F_m , in which case F_m is used as the loss rate. Typically in 100-year storm studies, F^* serves as the loss rate for the entire storm pattern except for the most intense rainfalls where F_m would apply. However for lower frequency storm studies such as the 5-year return event, F^* often applies for the entire 24-hour storm pattern. The example problem of section E provides an illustration in the use of F^* and F_m values. Figure C-5 illustrates the loss rate function used with the design storm.

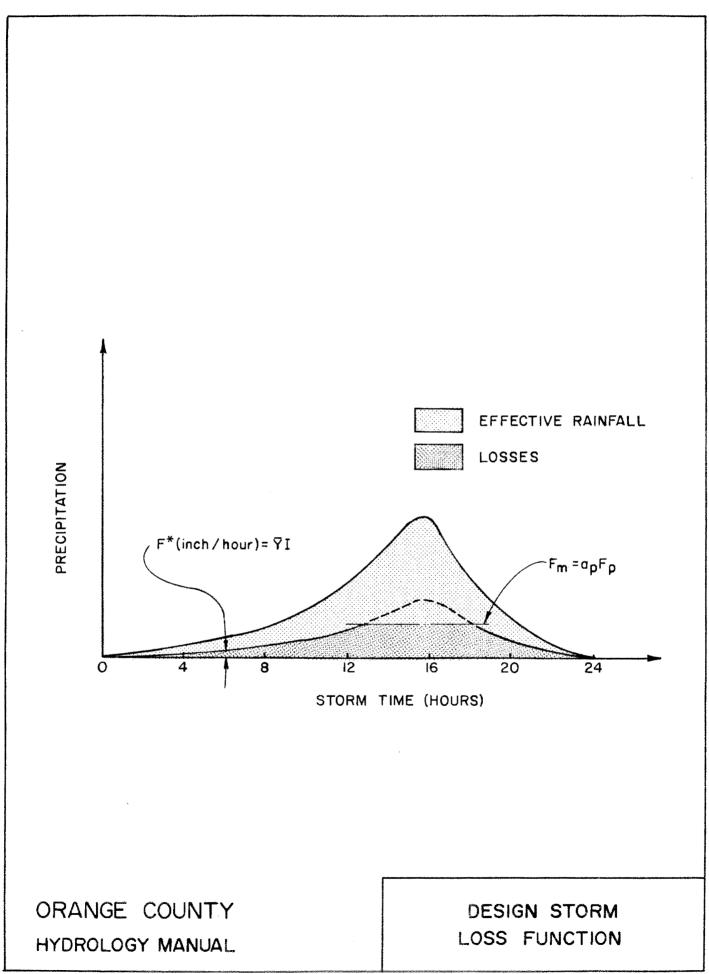


Figure C-5

SECTION D

RATIONAL METHOD

D.1. RATIONAL METHOD EQUATION

The rational method was originally developed to estimate runoff from small (less then one square mile) urban and developed areas and its use shall be limited to those conditions. Basically, the rational method equation relates rainfall intensity, a runoff coefficient, and drainage area size to the direct peak runoff from the drainage area. This relationship is expressed by the equation:

$$Q = CIA (D.1)$$

where

Q = the runoff in cubic feet per second (cfs) from a given area

C = a runoff coefficient representing the ratio of runoff to rainfall

I = the time-averaged rainfall intensity in inches per hour corresponding to the time of concentration

A = drainage area (acres)

The values of the runoff coefficient (C) and the rainfall intensity (I) are based on a study of drainage area characteristics such as type and condition of the runoff surfaces and the time of concentration. These factors and the limitations of the rational method equation are discussed in the following sections. Drainage area (A) may be determined by planimetering a suitable topographic map of the project area.

Data required for the computation of peak discharge by the rational method are: (i) rainfall intensity (I) for a storm of specified duration and selected

design frequency; (ii) drainage area characteristics of size (A), shape, slope; and (iii) a runoff coefficient (C).

D.2. LIMITATIONS OF THE RATIONAL METHOD

The validity of the relationship expressed by the rational method equation holds true only if certain assumptions are reasonably correct and limitations of the method are observed. Two basic assumptions are that (i) the frequency of a storm runoff is the same as the frequency of the rainfall producing this runoff; i.e., a 25-year recurrence interval rainfall will provide a 25-year recurrence interval storm runoff, and (ii) that the peak runoff occurs when all parts of the drainage area are contributing to the runoff. The use of the rational method equation is limited to watersheds of size less than 640 acres.

The rational method equation is only applicable where the rainfall intensity (I) can be assumed to be uniformly distributed over the drainage area at a uniform rate throughout the duration of the storm. This assumption applies fairly well to small areas of less than 640 acres. Beyond this limit, the rainfall distribution may vary considerably from the point values given in rainfall isohyetal maps and the rational method equation should not be used.

The selection of the runoff coefficient (C) is another major limitation for the rational method equation. For small urban and developed areas the runoff coefficient can be reasonably well estimated from field and aerial photo studies. For larger areas where the determination of the runoff coefficient is to be based on vegetation type, cover density, the infiltration capacity of the ground surface, and the slope of the drainage area, an estimate of the runoff coefficient may be subject to a much greater error due to the variability of the drainage area characteristics. Rainfall losses due to evaporation, transpiration, depression and channel storage are inadequately evaluated, and may appreciably affect the estimate of the watershed peak rate of runoff. The effects of depth-area-duration (or depth-area) factors are not accounted for in the simple intensity-duration curve used for rational method studies.

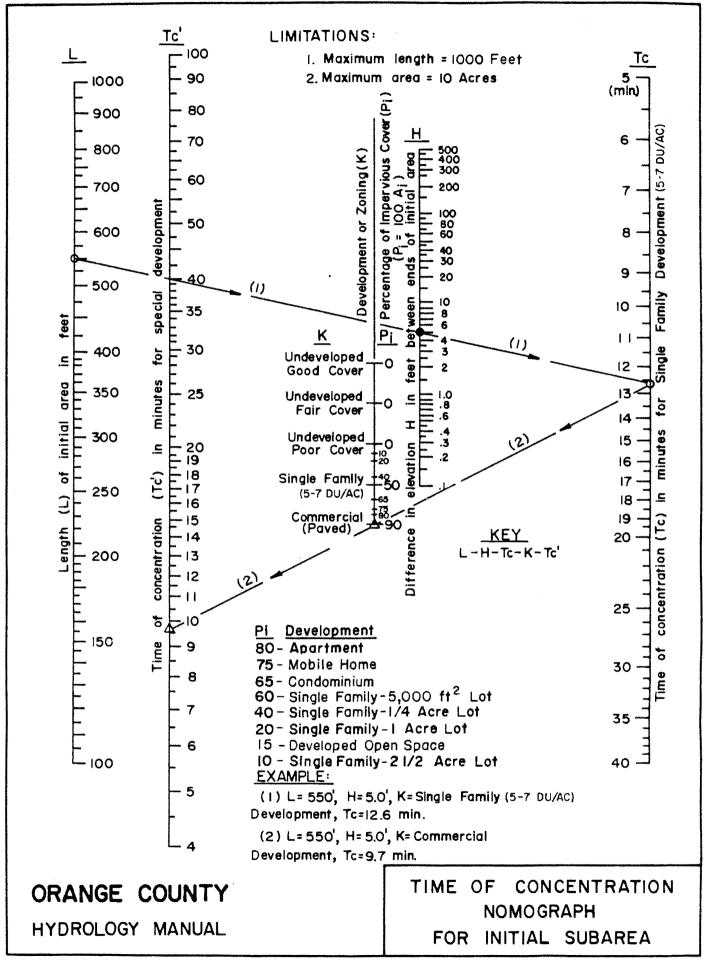
For large drainage areas, the absence of depth-area adjustments can result in significant differences in the estimate of the average depth of catchment point rainfalls.

The above limitations indicate that an estimate of the peak rate of runoff becomes less reliable as the drainage area becomes larger and the rational method equation should, therefore, not be used for drainage areas larger than 640 acres.

D.3. CRITICAL DURATION (TIME OF CONCENTRATION)

The critical duration of the storm rainfall required in the rational method equation is based on the time of concentration of the drainage area.

The time of concentration (Tc) is defined as the interval of time (in minutes) required for the flow at a given point to become a maximum under a uniform rainfall intensity. Generally, this occurs when all parts of the drainage area are contributing to the flow. Generally, the time of concentration is the interval of time from the beginning of rainfall for water from the hydraulically most remote portion of the drainage area to reach the point of concentration; e.g., the inlet of the drainage structure. The time of concentration is a function of many variables including the length of the flow path from the most remote point of an area to the concentration point, the slope and other characteristics of natural and improved channels in the area, the infiltration characteristics of the soil, and the extent and type of development. For rational method studies based on this manual, the time of concentration for an initial subarea may be estimated from the nomograph of Figure D-1. The time of concentration for the next downstream subarea is computed by adding to the initial Tc, the time required for the computed peak flow to travel to the next concentration point. Time of concentration is computed for each subsequent subarea by computing travel time between subareas and adding to the cumulative sum.



When the flow is concentrated in curb and gutters, drainage channels or conduits, the flow velocity may be estimated by the well-known Manning's equation

$$V = \frac{1.49}{D} R^{2/3} S^{1/2}$$
 (D.2)

where

V = mean velocity (fps)

n = Manning coefficient of roughness (see Design Manual)

R = hydraulic radius (feet)

S = energy slope which equals the conduit invert slope for uniform flow

The travel time will then be the flow distance divided by the velocity of flow.

Computations of travel time through subareas which continually add to the peak flow (e.g., streetflow) should be based on the average peak flow through the subarea. This average peak flow is generally a simple average of the peak flow rates estimated at the upstream and downstream points of the subarea.

The initial subarea Tc estimation often is the most significant factor leading to the Tc computation of a watershed. Small development studies typically utilize only initial subarea estimations due to the small subarea sizes. Larger study areas generally show high sensitivity to the initial subarea Tc. Consequently, judgment is needed when developing initial subarea Tc estimates. The nomograph of Figure D-1 is based on the Kirpich formula and relates an initial subarea Tc to subarea slope and development type. It is assumed in the nomograph that overland flow effects dominate the travel time hydraulics.

It is noted that the Tc computation procedure is based upon the summation of an initial subarea time of concentration with the several travel times estimated by normal depth flow-velocities through subsequent subareas.

D.4. INTENSITY-DURATION CURVES

The precipitation intensity-duration curves presented in Section B.3 (Figures B-3 and B-4) are appropriate for the rational method.

D.5. RUNOFF COEFFICIENT

The runoff coefficient (C) is the ratio of rate of runoff to the rate of rainfall at an average intensity (I) when the total drainage area is contributing. The selection of the runoff coefficient depends on rainfall intensity, soil infiltration rate (F_p), and impervious and pervious area fractions (a_i and a_p).

Since one acre-inch/hour is equal to 1.008 cfs, the rational formula is generally assumed to estimate a peak flowrate in cfs. Runoff coefficient curves are developed using the relationship:

$$C = \begin{cases} 0.90 \text{ (a}_{i} + \frac{(I - F_{p})a_{p}}{I} \text{), for I greater than } F_{p}; \\ 0.90 \text{ a}_{i}, \text{ for I less than or equal to } F_{p} \end{cases}$$
(D.3)

where the proportion factor of 0.90 is a calibration constant determined by an average fit between the rational method and design storm unit hydrograph (see Section E) peak flow rate estimates, and where

> C= runoff coefficient

I = rainfall intensity (inches/hour)

= infiltration rate for pervious areas (inches/hour) F_{D}

(see Section C.6.4)

= ratio of impervious area to total area (decimal a;

fraction)

ratio of pervious area to total area (decimal

fraction), $(a_p = 1 - a_i)$

D.6. PEAK FLOW RATE FORMULA

Combining Equations (D.1) and (D.3), the peak flow estimate for Q is written in simpler terms by

$$Q = .90 (I - F_m)A$$
 (D.4)

where $F_m = a_p F_p$ (see section C.6.5), and where in (D.4) it is understood that I is greater than F_p ; otherwise $Q = .90 \, a_i IA$.

In (D.4), F_m represents the loss rate for the total watershed tributary to the point of concentration. Should the tributary area contain several runoff surfaces, an area-averaged F_m is calculated. Table D.1 illustrates such an area-averaged F_m computation.

TABLE D.1. AREA-AVERAGED Fm COMPUTATION

Subarea Number (1)	a _p (2)	Soil Group (<u>3)</u>	F _p (inch/hour) (4)	Area (acres) (<u>5)</u>	Area Weighting <u>of (4)</u>
1	0.60	А	0.40	8	1.92
2	0.80	В	0.30	12	2.88
3	0.75	C	0.25	11	2.06
4	0.10	D	0.20	15	0.30
5	0.50	С	0.25	16	2.00
				62	9.16

From Table D.1., the area-averaged maximum loss rate, F_m , is given by $F_m = (9.16)/(62) = 0.147$ inch/hour, say 0.15.

D.7. DRAINAGE AREA

The contributing drainage area may be determined from topographic contour maps, aerial photos, and field surveys. Watershed divides are then drawn on a suitable topographic map and the enclosed drainage area is determined by planimeter or other methods. In areas where lateral and transverse slopes on the watershed are very mild, the nominal watershed area (or drainage subdivision) runoff may "cascade" under severe rainfall. That is,

when the divide between one watershed and another is defined by a low relief feature such as the crown of a road, the runoff from such a watershed may "spill over" into the adjacent watershed or watershed subdivision. This may occur, for example, when gutter capacity is exceeded thereby increasing runoff contributions at downstream or adjacent concentration points above those anticipated by analysis of the nominal or "low flow" drainage boundaries. The possibility of such cascading shall be considered and provided for by the hydrologist.

D.8. RATIONAL METHOD CONFLUENCE ANALYSIS

In most studies, the calculation of peak flow rates along a main channel or stream involves only the direct application of (D.4). Such studies typically involve the inclusion of subarea runoff to the stream where the effect on the stream peak flow rate is relatively minor and, consequently, only (D.4) is needed for the analysis.

At the junction of two or more streams, however, the estimation of the peak flow rate involves a confluence analysis of the associated runoff hydrographs (see Appendix III).

For the confluence of two streams, let T_1 , I_1 , Fm_1 , A_1 , and Q_1 , be the time of concentration, rainfall intensity, area-averaged loss rate, catchment area, and peak flow rate for stream #1 while T_2 , I_2 , Fm_2 , A_2 and Q_2 correspond to stream #2. Also, let Q_1 be less than Q_2 . Finally, let T_p , A_p , and Q_p be the resulting confluence estimates for Tc, area, and peak flow rate, respectively. Then two cases are possible:

*Case 1: $T_1 = T_2$. The runoff hydrographs must both peak at $T_p = T_1 = T_2$. And $Q_p = Q_1 + Q_2$ for a total contributing area of $A_p = A_1 + A_2$.

*Case 2:

 $T_1 \neq T_2$. In this case, the sum of the two runoff hydrographs must be considered. Except in very unusual conditions, flow rates of the summed runoff hydrograph typically achieve a maximum at either T_1 or T_2 , and the peak flow rate estimates are calculated as follows:

Case 2a:

 T_1 is less than T_2 . In this case, the stream with the largest Q has the longest T_c . The flow rate of the summed runoff hydrograph at time T_2 is estimated by

$$Q_p = Q_2 + \frac{(I_2 - Fm_1)}{(I_1 - Fm_1)} Q_1$$
 (D.5)

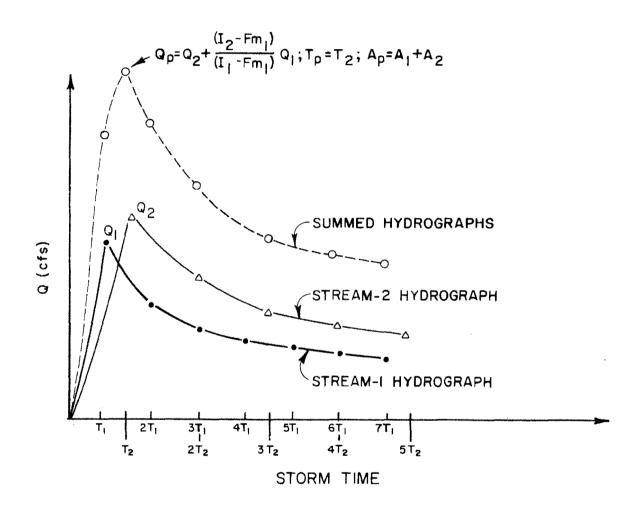
and $T_p = T_2$ (see Figure D-2). It is noted that the confluence peak Q of (D.5) equals the peak flow rate estimated from direct use of (D.4). Additionally, the total contributing area is $A_p = A_1 + A_2$.

Case 2b:

 T_1 is greater than T_2 . In this case, the stream with the largest Q has the shortest Tc. The flow rate of the summed runoff hydrograph at time T_1 is estimated using a ratio of stream 1 effective rainfall intensities and Tc values corresponding to times T_2 and T_1 giving

$$Q_p = Q_2 + \frac{(I_2 - F_{m_1})}{(I_1 - F_{m_1})} \frac{(T_2)}{(T_1)} Q_1$$
 (D.6)

and $T_p = T_2$. Equation (D.6) indicates that the peak flow rate at time T_2 is the result of the high peak discharge from stream 2 and the runoff contribution from a fraction of the stream 1 catchment area.



ORANGE COUNTY HYDROLOGY MANUAL RATIONAL METHOD
CONFLUENCE ANALYSIS
(Summation of Runoff Hydrographs)

That is, a portion of the catchment tributary to stream I is not contributing at time T_2 and, in the general case, only $(T_2/T_1)A_1$ of the stream I catchment area is contributing to the peak flow rate (at time T_2). Consequently for downstream study purposes, the "effective" catchment area corresponding to the subject peak flow rate is

$$A_p = A_2 + (T_2/T_1)A_1$$
 (D.7)

It is noted that in the confluence peak flow rate estimate of (D.6), the critical duration is $T_p = T_2$ which corresponds to the effective catchment area of (D.7) Consequently, the peak flow rate contribution from the effective catchment area of stream 1 must reflect the higher rainfall intensity corresponding to time T_2 rather than time T_1 . Use of (D.6) results in a peak flow which equals the governing rational method peak flow rate estimate from (D.4) applied to the effective catchment area computed by (D.7). It is noted that the estimation of the effective catchment area is only an approximation, and shall be verified by the hydrologist.

D.9. RATIONAL METHOD To CALCULATIONS FOR UNIT HYDROGRAPH STUDIES

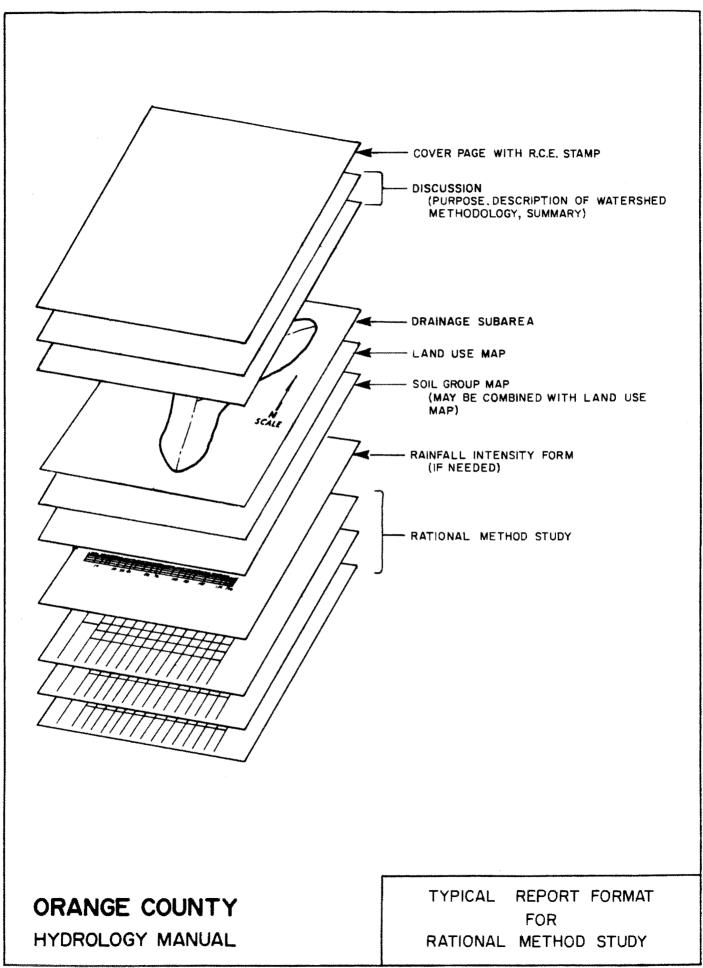
Although the peak flow rate formula should generally not be used for catchments larger than I square mile, the rational method can be used to estimate Tc values for larger areas. That is, the rational method estimate for Tc in large areas is adequate for use in the unit hydrograph studies of section E. T-year storm estimates for Tc are determined for areas less than I square mile using the T-year intensity-duration curves and the appropriate Fm values to generate cfs/acre estimates. For larger areas, cfs/acre estimates for use in the rational method are obtained from the cfs/acre curves of section L.

D.10. REQUIRED FORMAT

Figure D-3 illustrates the required format for the submittal of rational method hydrology studies. All rational method calculations must be summarized on the form shown in Figure D-4.

D.11. INSTRUCTIONS FOR RATIONAL METHOD HYDROLOGY CALCULATIONS

- 1. On a topographic map of the drainage area, draw the study drainage system and designate subareas tributary to the various points of concentration (see example problem).
- 2. Determine the initial time of concentration, (Tc), using Figure D-1. The initial subarea should be less than 10 acres, have a flow path of less than 1,000 feet, and generally should be the most upstream subarea of the watershed drainage system.
- 3. Using the time of concentration, determine (I) (intensity of rainfall in inches per hour) from the appropriate intensity-duration curve for the particular area under study using Figures B-3 and B-4.
- 4. Calculate the area-averaged maximum loss rate, $F_{\rm m}$, which corresponds to the soil group, cover complex, and imperviousness of the drainage subarea. Loss rates for the pervious area, $F_{\rm p}$, follow from section C.6.4.
- 5. Determine the area (A, acres) of the <u>total</u> watershed tributary to the point of concentration. Because the rational method computational results are sensitive to the subarea size definitions (especially in the most upstream reaches of the watershed), limit the size of subareas to allow for a gradual increase in subarea size as the study progresses downstream. The method is sensitive to large differences in successive subarea shapes, and lengths of reaches where travel times are estimated. Points of concentration should be selected downstream of the initial subarea such that subarea travel



ORANGE COUNTY HYDROLOGY MANUAL		STUDY NAME: -YEAR STORM RATIONAL METHOD STUDY											Date		
			T											'age of	
Concentration Point	Area (Subarea	(Acres) Total	Soil Type	Dev. Type	T _† min.	T _C min.	I in/hr	Fm in/hr	F m avg.	Q Tatal	Flaw Path Length ft.		V ft./sec.	Hydraulics and Notes	

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times are less than 3-minutes and 5-minutes for Tc values of 30-minutes and 60-minutes, respectively. After a Tc of 1-hour, subarea travel times should be limited to less than 10-minutes.

- 6a. Compute $Q = .90 (I-F_m)A$ for the point of concentration.
- 6b. Should the computed Q be less than the previous upstream point of concentration Q, use the upstream Q value.
- 7. Measure the length that the peak runoff must travel to the point of concentration of the next downstream subarea. Determine the average velocity of flow in this reach using the peak Q in the appropriate type of conveyance being considered (natural channel, street, pipe, or open channel) using Manning's formula. Where necessary, the mean flow in the conveyance (e.g., streetflow) should be used to compute mean flow velocity.

Using the reach length and average flow velocity, compute the travel time and add to the time of concentration from the upstream subarea to determine a new time of concentration.

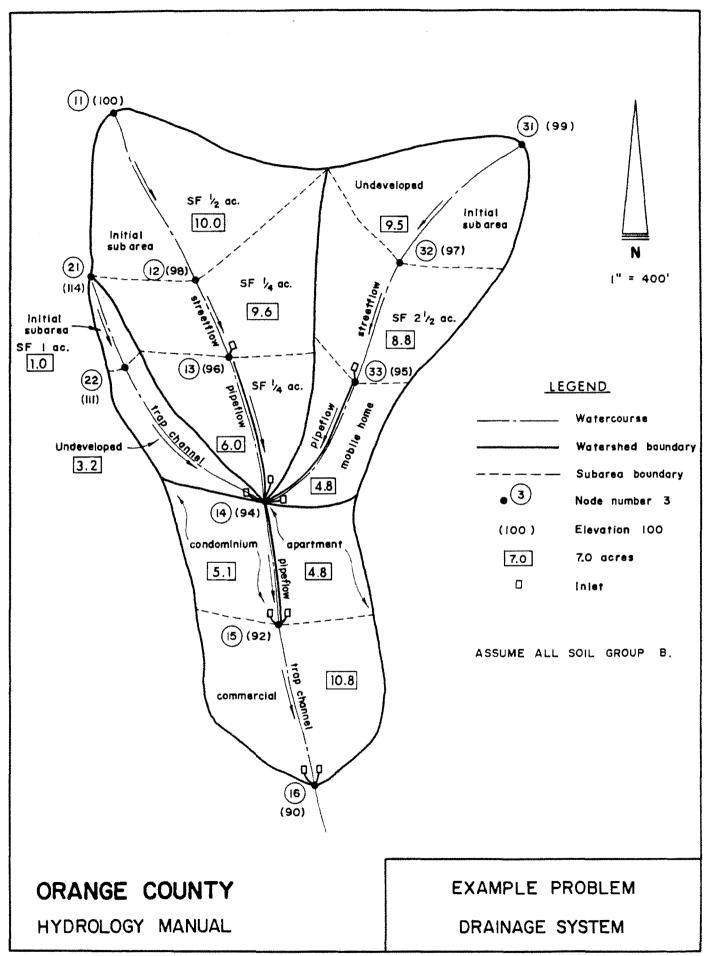
- 8. Calculate Q for the new point of concentration using steps 3 through 6 and the new time of concentration. Determine the time of concentration for the next downstream subarea using Step 7. Continue the above computation procedure downstream until a junction with a lateral drain is reached.
- 9. Start at the upstream end of the lateral and compute its Q down to the junction with the main line, using the methods outlined in the previous steps.
- 10. Compute the peak Q at the junction (confluence analysis—see Section D.8) and evaluate the sensitivity of the computed results to using the other Q and Tc values determined. That is, the downstream estimated peak Q values may be higher had a lower Q and lower Tc value been used at an upstream confluence point. The largest Q is, therefore, estimated along the entire watershed main channel.

D.12. EXAMPLE PROBLEM

The following example problem illustrates the format required for rational method hydrology studies. In the following, an example watershed is analyzed using the rational method approach. Additional and expanded examples are contained in the Hydrology Manual Workbook which can be obtained separately from the Agency. The example problem presentation contains the following information:

Description

- o Example Problem Drainage System Map
- o Example Problem Rational Method Calculation Sheets



ORANGE CO			•			LE PA			YOU		•	ted by _ ked by _	MHS	Date <u>5-/2-86</u> Date <u>5-/2-86</u> Page of2
Concentration Point	Areo (Subarea	Acres) Total	Soil Type	Dev. Type	T _t min.	T _C	I in/hr	Fm in/hr	Fm avg.	Q Total	Flow Path Length ft.	Slope ft./fl.	V fl./sec.	Hydraulics and Notes
12.00	10.0	10.0	B	SF(1/2)		21.0	1.78	0.21	0.21	14.2	800	0.0025		INITIAL SUBAREA 44 ft. Street
					2.3		<u> </u>		 		350	0.0057	2.5	QAVG=20.4 Dn= 0.55 ft
13.00	9.6	19.6	B	SF(1/4)	1,9	23.3	7.68	0.18	0.20	26.1	650	0.0031	5.6	33" RCP
14.00	6.0	25.6	B	SF(1/4)		25.2	1.61	0.18	0.19	32.7				STREAM BUMMARY
14.00		25.6				25.2				32.7				
22.00	1.0	1.0	В	SF(1)		13.7	2.28	0.24	0.24	1.8	400	0.0075		INITIAL BUBAREA
			-	37(1)	3.0					-	850	0.020	4.7	8:0.5' 2:2.0 n:0.015 Dn:0.33
14,00	3.2	4.2	8	UNDEV.		16.7	2.03	0.30	0.29	6.6				STREAM SUMMAR
14.00		4.2				16.7				6.6				
32.00	9.5	9.5	B	UNDEV.		42.0	1.20	0.30	0.30	7.7	750	0.0027		INITIAL SUBAREA
**************************************	00	100		arbul	5./	17)	1 10	0.07	0.00	110	550	0.0036	1.8	0AVG : 10.9 Dn : 0.49 ft
33.00	8.8	18.3	B	3F(21/2)	3.3	47.1	1.12	0.27	0.29	14.0	700	0.0014	3.5	30" RCP n=0.018 Pn=1.88
14.00	4.8	23./	B	MH		50.4	1.08	0.08	0.24	17.5		0.00		
14.00		23.1				50.4				17.5				STREAM SUMMARY
			[1.60	-0.29	1		125.21	11.61	-0.24					
\overline{Q} ,	= 32.7	+(6.6)	2.03	-0.29		(17.5)	50.4)	1.08	-0.24	= 52.0				CONFLUENCE ANALYSIS FOR
$\overline{Q}_{\mathbf{z}}$	= (32.7)	76.7 25.2 1.60			+	(17.5)	(<u>16.7</u>) 50.4	$(\frac{2.03}{1.08})$	0.24	47.0				PT: # 14.00
	=(32.7)	(1.08 -	0.19		<u> </u>	(6.6)	1.08	-0.29 -0.29)	+17.5=	41.0				
A=25.6 + 4.2 +	25.5 50.4 (23.1)	= 41.4	0.19		+	25.2	(2.03	-0.29/		52.0				CONFLUENCE RESULTS
	en e				 									

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ORANGE CO	UNTY	STUD	Y NAN			LE PR		M od stu	IDY	, , , , , , , , , , , , , , , , , , ,	Calcula Chec	ted by _i ked by _	MHS	Date <u>5./2.86</u> Date <u>5./2.86</u> Page <u>2</u> at <u>2</u>
Concentration Point	Area Subarea	(Acres)	Soil Type	Dev. Type	T _t min.	T _C	I in/hr	Fm in/hr	Fm avg.	Q Total	Flow Poth Length ft.	Slope ft./fl.		
15.00	5.1	46.5	B	contoo	1.3	26.5	1.56	0.11	-			0.0036	7./	ADDITION OF
15.00	4.8	51.3	B	APT		26.5	1.56	0.06	0.19	63,3				5UBAREA n=0.015 Pn=1.9
16.00	10.8	62.1	B	COM	2.1		1.49		0.16	<u></u>	700	0.0029	5.6	#=2.0 B=2.0 STREAM
16.00		62.1				28.6				74.3				SUMMARY
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SECTION E

THE UNIT HYDROGRAPH METHOD FOR CATCHMENT RUNOFF HYDROGRAPHS

E.I. BACKGROUND

The unit hydrograph method assumes that watershed discharge is related to the total volume of runoff, and that the time factors which affect the unit hydrograph shape are invariant, and that watershed storm rainfall-runoff relationships are characterized by watershed area, slope, and shape factors. The UH method is used to estimate the time distribution of watershed runoff in drainage basins where stream gage information is either unavailable or inadequate to justify statistical interpretation (refs. 4-10). The unit hydrograph method for determining the time distribution of runoff shall be used for hydrology studies of all Orange County watersheds in excess of 640 acres.

For a catchment of one (1) square mile (640 acres) or larger, where only the peak discharge is required, and where the Valley:Developed S-Graph applies, the Peak Flowrate Curves in Section L may be used.

E.2. TERMINOLOGY

The following definitions are used in the discussion of unit hydrograph and runoff hydrograph synthesis:

Effective rainfall is that part of rainfall that runs off in a relatively brief time period. (Here, the brief time period is selected sufficiently small such that the significant hydrologic effects are adequately represented by the time-period's average values.) Effective rainfall is the total rainfall less infiltration, evaporation, transpiration, absorption, and detention.

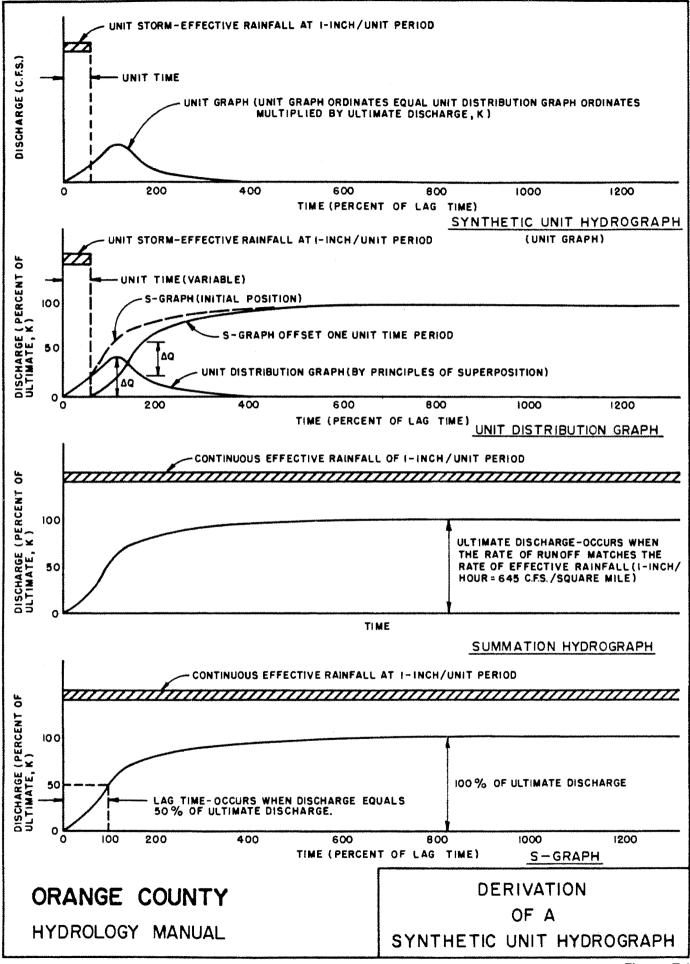
Unit hydrograph (or unit graph) for a point of concentration on a watershed (catchment) stream is a curve (hydrograph) showing the time distribution of rates of runoff which results from one inch of effective rainfall during a unit period of time over the tributary watershed upstream of the point of concentration. The unit effective rainfall is generally assumed to occur as an equivalent constant rainfall intensity during a specified unit period of time (such as 5, 10, 15 or 30-minutes). Figure E-1 illustrates the general formulation of the unit hydrograph.

<u>Distribution graph</u> is a unit hydrograph whose ordinates are expressed in terms of percent of ultimate discharge. A distribution graph is generally developed as a block graph with each block representing its associated percent of unit runoff which occurs during the specified unit time. The unit time used in the distribution graph is identical to the unit time specified for the unit hydrograph.

<u>Summation hydrograph</u> for a point of concentration on a given stream is a curve (hydrograph) showing the time distribution of the rates of runoff that would result from a continuous series of unit period effective rainfalls over the tributary watershed upstream of the subject point of concentration. The ordinates of the summation hydrograph are expressed in percent of the ultimate discharge.

Lag for a watershed is the time (hours) from the beginning of a continuous series of unit period effective rainfalls over the watershed area (tributary to a point of concentration) to the instant when the rate of resulting tributary watershed runoff (at the point of concentration) equals 50 percent of the ultimate rate of the resulting runoff.

<u>Ultimate discharge</u> is the maximum rate of watershed runoff which can result from a specified effective rainfall intensity. Ultimate discharge from a watershed occurs when the rate of runoff on the summation hydrograph is equivalent to the rate of effective rainfall. For an effective rainfall rate of one inch occurring in a unit period of one



hour, the ultimate discharge is 645 cfs for every square mile of watershed. Ultimate discharge for different unit periods is given by dividing 645 by the unit period in hours, and multiplying by the watershed area in square miles.

<u>S-Graph</u> is a summation hydrograph developed by plotting watershed discharge expressed in percent of ultimate discharge as a function of time expressed in percent of lag.

E.3. DETERMINATION OF SYNTHETIC DISTRIBUTION GRAPHS

Adequate storm rainfall and watershed runoff information are available for the determination of distribution graphs for several streams in Southern California. The distribution graphs for each of the gaged streams can be determined by trial-and-error attempts to duplicate the runoff hydrographs produced by major storm events (i.e., reconstitution studies). The derived distribution graphs are then verified by using them to reproduce runoff hydrographs from other major storm events.

The method of determining synthetic distribution graphs is used to estimate the time distribution of watershed runoff in drainage basins where stream gage data is inadequate. The procedure develops a time distribution of runoff based on the properties of distribution graphs from several gaged watersheds (refs. 4-10).

It is assumed that the drainage areas within a given region are physiographically and hydrologically similar. Because no two drainage areas have identical hydrologic characteristics, the runoff patterns from these areas are generally dissimilar and the distribution graphs of these areas may differ considerably. Therefore, direct transposition of distribution graphs from one watershed to another is usually precluded. However, most distribution graphs exhibit certain similarities which the introduction of a factor called "lag" will bring the arrangement of ordinates along the bases of distribution graphs into a generally consistent relationship. Lag, which was first defined as the time

difference in phase between salient features of the rainfall and runoff rate curves, is an empirical expression of the hydrologic characteristics of a watershed in terms of time. Details of the determination of lag for watersheds where the time distributions of runoff are known and of the use of lag in developing synthetic distribution graphs are discussed in the following:

- 1. <u>Summation Hydrograph</u> The first step in determining lag for a watershed is the determination of the summation hydrograph, which is the hydrograph of runoff that would result from the continuous generation of unit effective rainfall over the watershed. The ordinates of summation hydrographs are expressed in percent of ultimate discharge and a summation hydrograph for a point of concentration is determined by adding a continuous series of identical distribution graphs out of phase one unit period. On such a hydrograph, the time required to reach maximum (ultimate) discharge is equal to the length of the base of one distribution graph less one unit period.
- 2. Lag Lag for a watershed can be defined as the elapsed time (in hours) from the beginning of unit effective rainfall to the instant that the summation hydrograph for the point of concentration reaches 50 percent of ultimate discharge. When the lags determined from summation hydrographs for several gaged watersheds are correlated to the hydrologic characteristics of the watersheds, an empirical relationship is usually apparent. This relationship can then be used to determine the lags for comparable drainage areas for which the hydrologic characteristics can be determined, but for which the distribution graphs for concentration points cannot be determined because of inadequate hydrologic data. By comparing lag values (obtained from the analysis of rainfall-runoff data) to catchment time of concentration Tc values estimated from either a detailed rational method analysis (Section D) or use of the peak flowrate curves of section L, a relationship is readily determined,

$$lag = 0.8Tc (E.1)$$

It is noted that the rational method time of concentration, used for the estimation of basin lag time, is a critical parameter in the unit hydrograph method. Extreme care must be taken in the evaluation of the catchment Tc in order to reduce uncerainty, and enable "reproducibility" of this parameter. Section D provides the procedure for estimating Tc using the rational method for small areas. For larger areas, the Tc estimation procedure follows the methods of section D except that cfs/acre values are estimated using the cfs/acre curves of section L.

Lag = 0.8Tc (E.1) is used in all unit hydrograph studies where sufficient topographic information is available to compute the time of concentration, Tc. It is noted that due to Tc being the sum of the rational method's initial subarea Tc and the subsequent downstream reach hydraulic traveltimes, Tc values will vary depending on the return frequency of rainfall used in the analysis. That is, a 2-year storm estimated Tc value typically is longer in duration than a 100-year storm estimated Tc value. Consequently, when computing the lag corresponding to a T-year design storm event, the Tc is estimated using the T-year intensity-duration rainfalls in the rational method, or by using the T-year peak flowrate curves. For certain large scale natural condition catchment studies (e.g., Carbon Canyon, Santiago Creek, Trabuco Creek, San Juan Creek) the Agency may consider the use of the lag relationship given by the empirical formula:

$$lag (hours) = C_t ((L \cdot L_{ca})/S^{0.5})^m$$
 (E.2)

where

Ct = a constant (determined by regional flood reconstitution studies)

L = length of longest watercourse (miles)

L_{Ca} = length along longest watercourse, measured upstream to a point opposite center of area (miles)

S = overall slope of drainage area between the headwaters and the collection point (feet per mile)

m = a constant determined by regional flood reconstitution studies

It is then assumed that there exists a relationship between watershed lag and the quotient $((L \cdot L_{Ca})/(S^{0.5}))^m$. This relationship is given by the above empirical formula for lag when

 C_t = 24 \overline{n} ; (\overline{n} is the visually estimated basin factor of all collection streams and watershed channels, see Figure E-2)

m = 0.38

3. <u>S-graph</u> - After lag factors are determined for several gaged watersheds the next step in determining synthetic distribution graphs is the development of S-graphs, which are summation hydrographs modified so that the percent of ultimate discharge is related to time expressed in percent of lag. The derivation of an S-graph is identical to the derivation of a summation hydrograph, except that the factor of lag has been introduced. Time in percent of lag has been used to determine S-graphs for four major groupings of watersheds.

Four S-graphs are used for unit hydrograph development in Orange County. These S-graphs are entitled Valley: Developed, Valley: Undeveloped, Foothill, and Mountain (Figures E-3a, b, c, d). In conformity with the definition of lag, each S-graph reaches 50 percent of ultimate discharge at 100 percent of lag. The average of the several S-graphs determined for mountain watersheds is assumed to be applicable to the mountain drainage basins with unknown runoff characteristics. Similarly the average of the S-graphs determined for valley watersheds is assumed to be applicable to the valley drainage basins, Use of the Foothill S-graph is only for watersheds characterized by natural channels that are sharply incised in canyon bottoms, i.e., overbank flows are confined near the defined channel. Use of the Mountain S-graph is only for watersheds characterized by natural channels with numerous plunging flow reaches and lodged boulders/debris. Use of the Valley: Undeveloped S-graph is for natural watersheds whose channels are not sharply incised, i.e., where overbank flows may spread widely from the defined channel. Use of the Valley: Developed S-graph is for all watershed conditions where prismatic channels exist or are to be provided for conveyance of T-year peak flows.

$\bar{n} = 0.015$

- 1. Drainage area has fairly uniform, gentle slopes
- 2. Most watercourses either improved or along paved streets
- Groundcover consists of some grasses large % of area impervious
- 4. Main water course improved channel or conduit

$\bar{n} = 0.020$

- Drainage area has some graded and non-uniform, gentle slopes
- Over half of the area watercourses are improved or paved streets
- 3. Groundcover consists of equal amount of grasses and impervious area
- 4. Main watercourse is partly improved channel or conduit and partly greenbelt (see n = 0.025)

$\bar{n} = 0.025$

- 1. Drainage area is generally rolling with gentle side slopes
- Some drainage improvements in the area streets and canals
- 3. Groundcover consists mostly of scattered brush and grass and small % impervious
- 4. Main watercourse is straight channels which are turfed or with stony beds and weeds on earth bank (greenbelt type)

$\bar{n} = 0.030$

- Drainage area is generally rolling with rounded ridges and moderate side slopes
- 2. No drainage improvements exist in the area
- 3. Groundcover includes scattered brush and grasses
- 4. Watercourses meander in fairly straight, unimproved channels with some boulders and lodged debris

$\bar{n} = 0.040$

- Drainage area is composed of steep upper canyons with moderate slopes in lower canyons
- 2. No drainage improvements exist in the area
- Groundcover is mixed brush and trees with grasses in lower canyons
- 4. Watercourses have moderate bends and are moderately impeded by boulders and debris with meandering courses

$\bar{n} = 0.050$

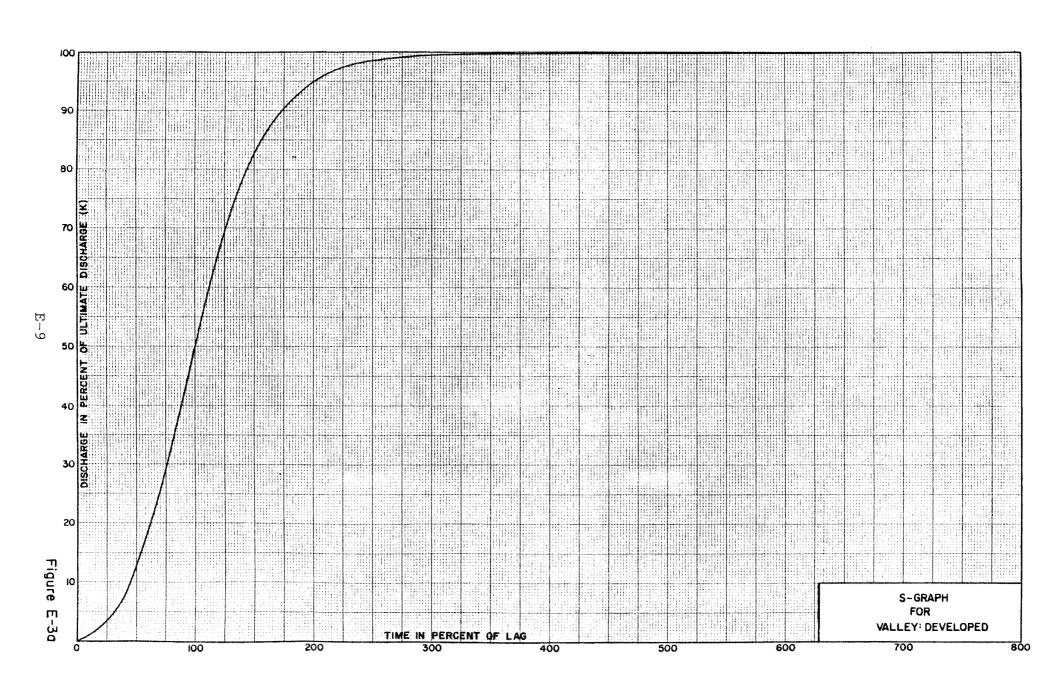
- Drainage area is quite rugged with sharp ridges and steep canyons
- 2. No drainage improvements exist in the area
- 3. Groundcover, excluding small areas of rock outcrops, includes many trees and considerable underbrush
- 4. Watercourses meander around sharp bends, over large boulders and considerable debris obstruction

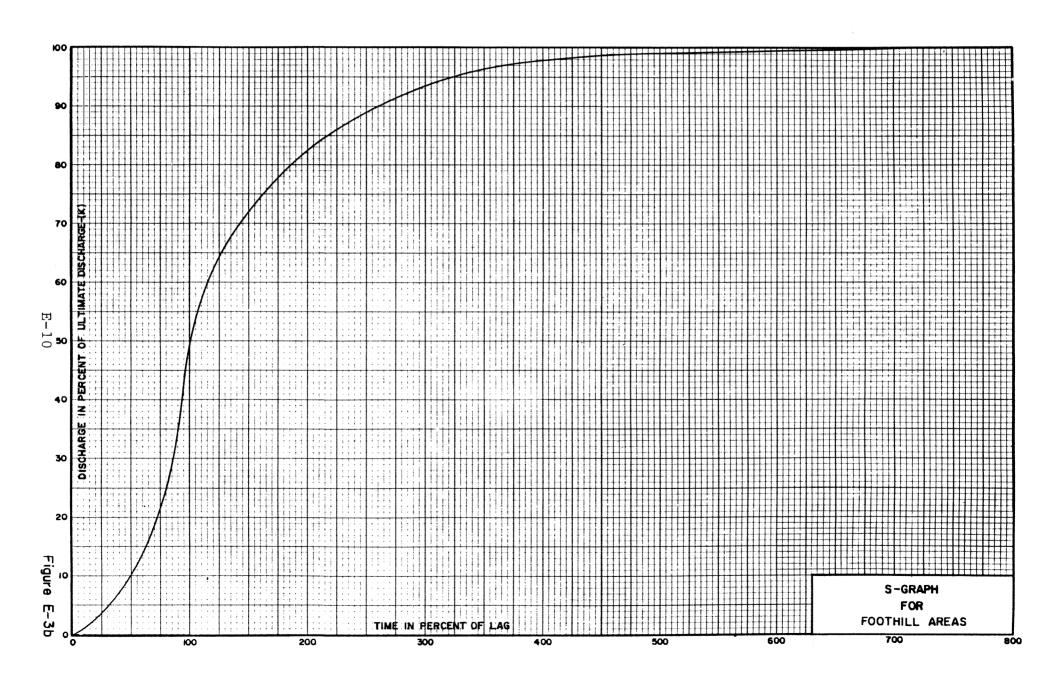
$\bar{n} = 0.200$

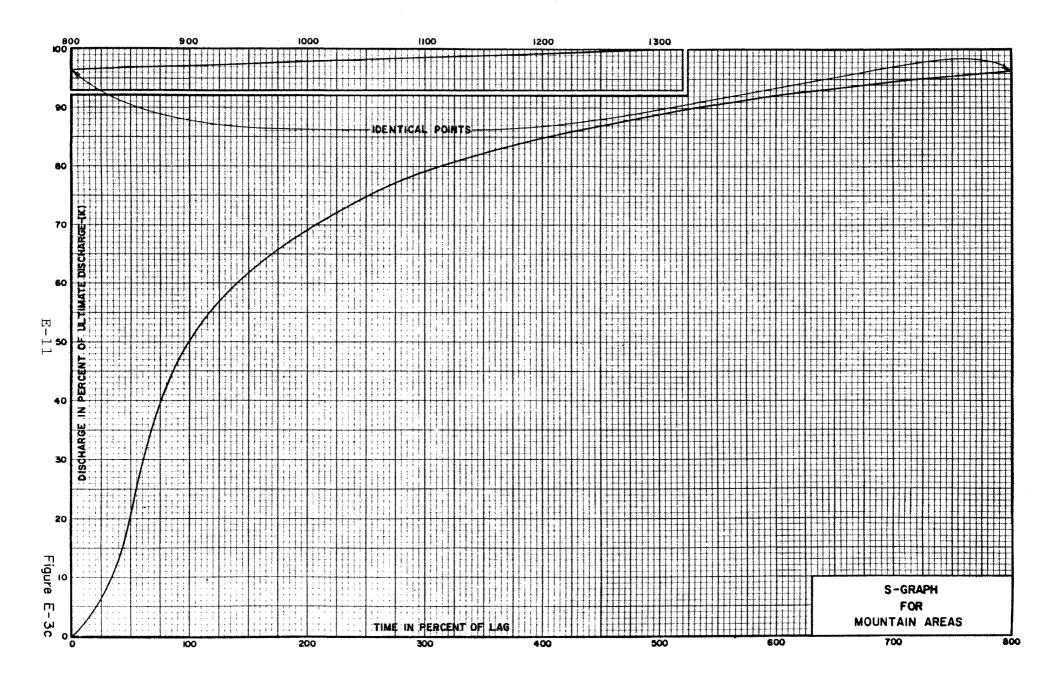
- 1. Drainage area has comparatively uniform slopes
- 2. No drainage improvements exist in the area
- 3. Groundcover consists of cultivated crops or substantial growths of grass and fairly dense small shrubs, cacti, or similar vegetation
- 4. Surface characteristics are such that channelization does not occur

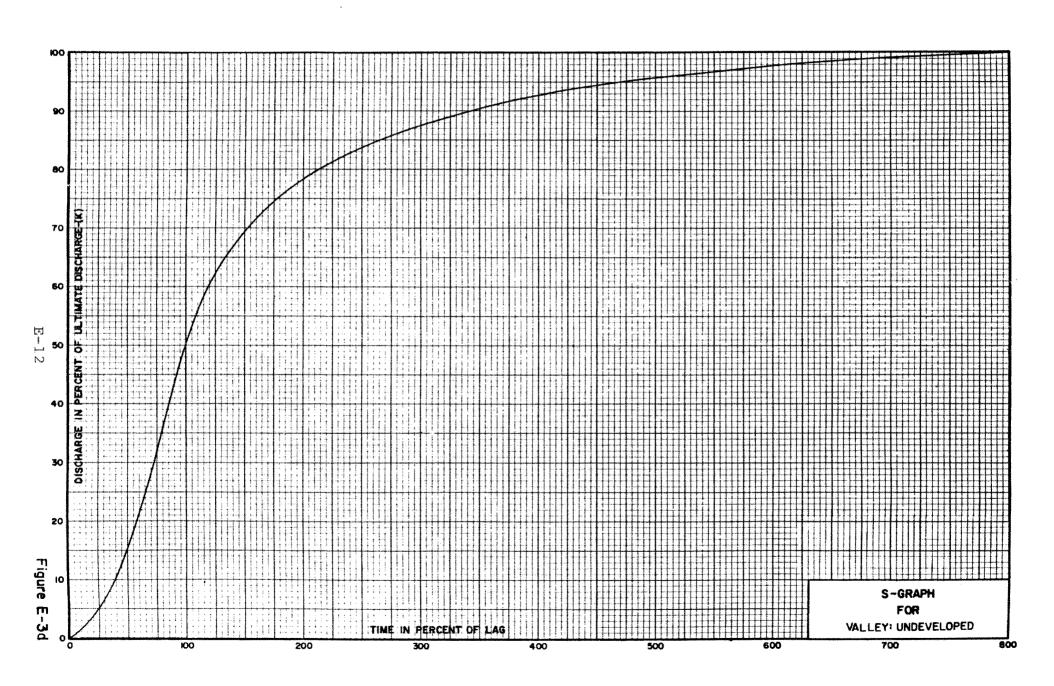
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HYDROLOGY MANUAL

BASIN FACTOR
DESCRIPTIONS









E.3.1. Application of Lag and S-graphs

Using the rational method, the watershed time of concentration (Section D) is computed and lag is determined using (E.1). A unit time is selected (generally 15 to 25 percent of the lag) and accumulated unit time periods are expressed as accumulated percentages of the watershed lag. These percentages of lag are used in superimposing a "block" graph on the appropriate average S-graph for the watershed and the resulting pattern is used in determining the accumulated mean percentage of ultimate discharge for each accumulated unit time (see example problem). Because these accumulated mean percentages represent the accumulated mean percentages for the synthetic distribution graph for the watershed, the mean percentage for successive unit periods are determined by a series of subtractions.

E.4. DEVELOPMENT OF THE SYNTHETIC UNIT HYDROGRAPH

For watersheds where stream gage data is inadequate, it may generally be assumed that a synthetic unit hydrograph adequately approximates the time distribution of runoff at the subject watershed point of concentration. From the above discussion, a method to develop a synthetic unit hydrograph is described in the following steps:

- 1. Estimate the watershed lag using topographic information and a rational method Tc calculation based on the appropriate T-year rainfall.
- 2. Select a unit period to be used for the hydrograph analysis. This unit period will be used for development of design critical storm unit rainfalls and the runoff hydrograph. The unit period is generally chosen to be within 15 and 25 percent of the watershed lag in order to provide sufficient definition of the unit hydrograph.
- 3. An S-graph is chosen which is appropriate for the catchment being studied.

- 4. The appropriate watershed S-graph can be approximated by a block graph where the base of each block is the selected unit period percentage of lag (Step 2) and the ordinate of each block is the time-averaged percentage of ultimate discharge (from the S-graph) for that unit period. The area of each block equals the area under the S-graph for each resulting pattern is used in determining the accumulated mean percentage of respective unit period. Consequently, at the end of each unit period the total area under the S-graph equals the sum of the areas of the equivalent unit period blocks.
- 5. The unit distribution block graph is developed by computing the difference between the ordinates (percentage of ultimate discharge) assigned to the unit period blocks used to approximate the S-graph of Step 4. This is equivalent to computing the difference between the ordinates of two S-graphs which have been offset by one unit period.
- 6. The final step to develop the synthetic unit hydrograph (or unit graph) is to multiply the ordinates of the distribution block graph (Step 5) by the factor K, the ultimate discharge. The ultimate discharge is defined by

$$K (cfs) = 645 A/T$$
 (E.3)

A = drainage area (square miles)

T = unit time period (hours)

E.5. DESIGN STORM PRECIPITATION DATA

The Agency's prescribed level of flood protection is obtained by using T-year rainfalls for the development of the T-year runoff hydrograph. Section B.4 provides the necessary information for developing the design storm pattern.

E.6. DESIGN STORM PATTERN

The design storm pattern is based upon a single synthetic 24-hour critical storm pattern which includes the peak rainfall intensities estimated for the 5-minute, 30-minute, 1-hour, 3-hour, 6-hour, and 24-hour durations. The storm pattern is developed from the watershed area-averaged point precipitation values, and modified incrementally according to the depth-area curves of Figure B-6. The assignment of peak rainfall values within the synthetic critical storm pattern is shown in Figure B-5(a,b,c) (refs. 4, 10).

For large watersheds (e.g., 5 square miles or larger) or for detention basin studies, the entire 24-hour synthetic storm pattern may be required for hydrologic study purposes. For small watersheds (less than 5 square miles) where only peak runoff rates are required, the peak 3-hours of the 24-hour synthetic storm pattern generally can be used for study purposes, ignoring the remaining 21-hours of lower intensity rainfall.

A detailed discussion of the design storm appropriate for the unit hydrograph method is presented in Section B-4.

E.7. DESIGN STORM LOSS RATES

Where sufficient stream gage information is of adequate quantity and quality as determined by the Agency, loss rates for unit hydrograph hydrology may be estimated from a study of rainfall-runoff relationships of major storms. Where such data is not available, loss rates for pervious areas shall be estimated using the methods of Section C.6.

E.7.1. Maximum Loss Rate, F_m

The maximum loss rate, F_m, for a catchment is computed by

$$F_{m} = a_{p}F_{p} \tag{E.4}$$

where

 $F_m = maximum loss rate (inches/hour)$

 a_D = pervious area fraction (see Figure C-4)

F_D = maximum loss rate for pervious areas (inches/hour);

(see Section C.6.4)

Maximum loss rates, $F_{\rm m}$, for runoff hydrograph studies are usually within the range of 0.05 to 0.25 inches per hour in urbanized areas. The range of values for the maximum loss rate for pervious areas, Fp is 0.20 to 0.40 in/hr. (see Table C.2).

E.7.2. Low Loss Rate, F*

During the peak rainfall intensities of the synthetic design storm pattern, the loss rate used to estimate effective rainfall is typically the maximum loss rate, F_m . At lower rainfall intensities, however, a low loss rate, F^* , is used for the estimation of effective rainfall. The low loss rate F^* is based upon the low loss fraction, \overline{Y} , defined by (see Section C.6.3)

$$\overline{Y} = 1 - Y \tag{E.5}$$

where

 \overline{Y} = catchment low loss fraction

Y = catchment 24-hour storm runoff yield fraction computed from (C.4)

The corresponding low loss rate based on the \overline{Y} value is

$$F^* = \overline{Y} \cdot I \tag{E.6}$$

where

F* = low loss rate (inches/hour)

 \overline{Y} = low loss fraction

I = rainfall intensity (inches/hour)

The low loss fraction should be used to estimate effective rainfall whenever the maximum loss rate, $F_{\rm m}$, exceeds F^* . In all cases, however, the maximum loss rate is the constant value, $F_{\rm m}$. Use of these two loss rate concepts enables the 24-hour design storm runoff hydrograph model to develop peak runoff rates based upon a maximum watershed loss rate (phi index), and also develop 24-hour storm runoff yields which approximate the values obtained from the curve number approach.

E.8. BASEFLOWS

Baseflow is usually a minor factor in developing flood hydrographs for relatively rare flood events in Orange County. Generally, 10 cfs per watershed square mile is adequate for unlined channels that intercept mountainous regions where many geologic strata are crossed by the stream bed. Baseflow can be included in the watershed runoff by adding to the ordinates of the computed runoff hydrograph. In fully urbanized areas, baseflow can be entirely neglected.

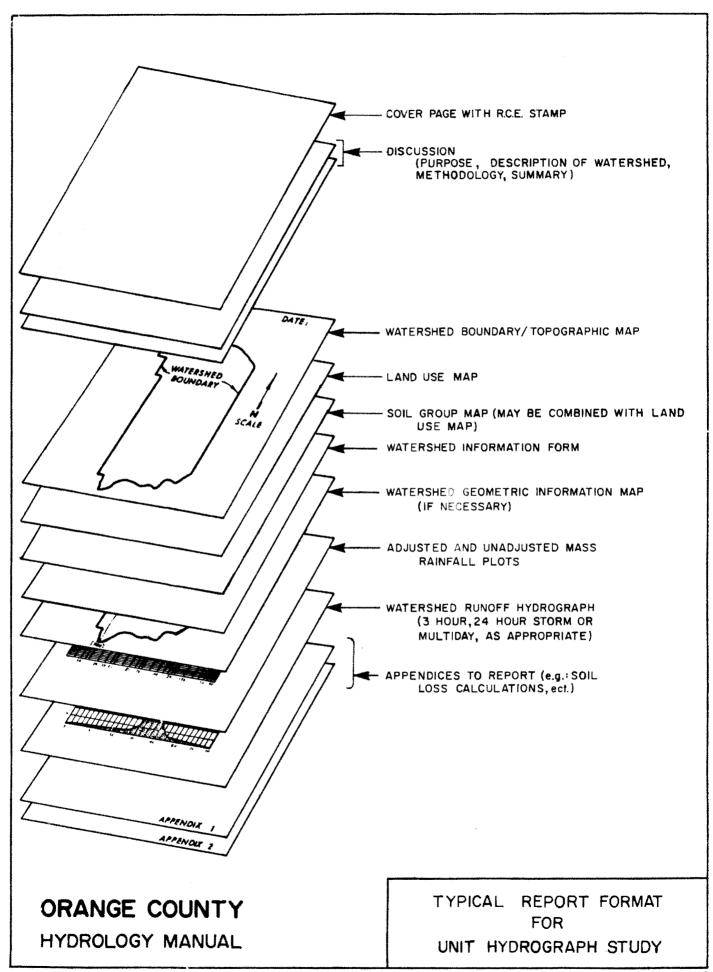
E.9. ALTERNATIVE RUNOFF HYDROGRAPH METHODS

The Orange County Hydrology Manual has been calibrated to local watershed conditions (without the use of channel routing parameters) in order that the unit hydrograph hydrologic methods achieve the desired level of protection in estimating the return frequency of floodflows. The introduction of additional parameters, in particular the routing of subarea flows, may alter the calibration, resulting in a failure to achieve the flood control protection level objectives. Because model sensitivity analysis and model calibration is essentially precluded for studies involving ungaged watersheds, any hydrologic study not prepared in accordance with this hydrology manual may be rejected (see Section K).

E.10. REQUIRED FORMAT

Figure E-4 illustrates the required format for submitting unit hydrograph study results for review.

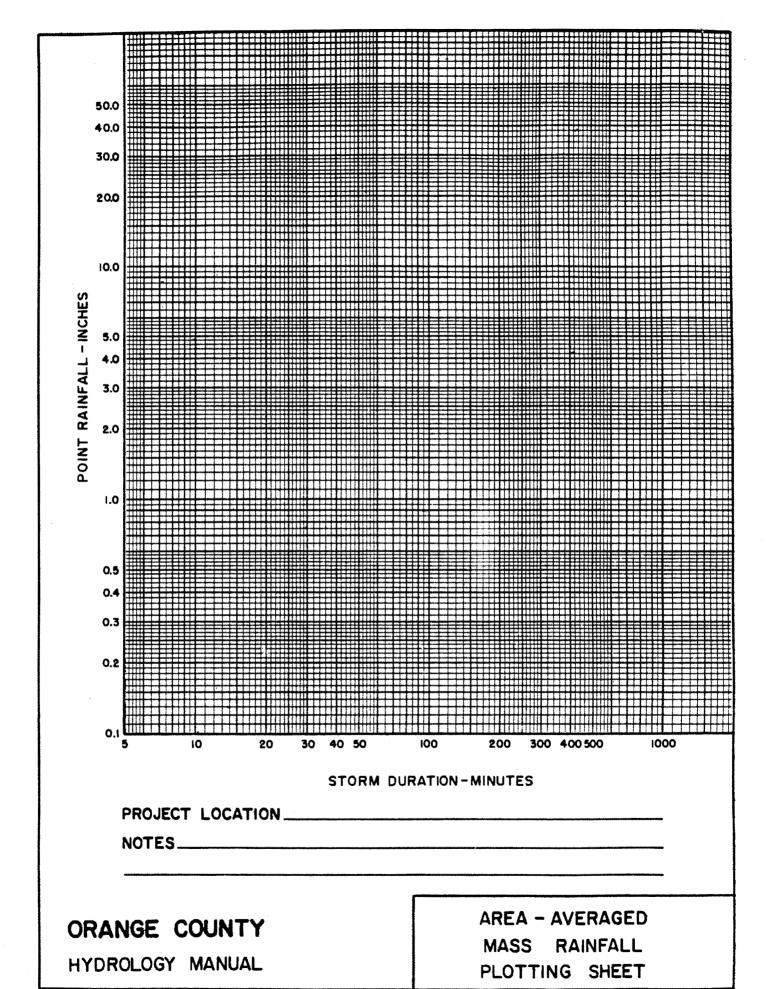
Figure E-5 is to be used to supply the necessary hydrology information to determine the runoff hydrograph. Figure E-6 is used to plot both the unadjusted and adjusted mass rainfall curves. The Flood Computation Form is contained in the pocket in the back of this manual.



PRO:	JECT:	DATE:	
ENG	INEER:		
1.	Enter the design storm return fre	quency (years)	
2.	Enter catchment lag (hours)	AMANAGARAN	
3.	Enter the catchment area (acres)	and the second s	
4.	Enter baseflow (cfs/square mile)		
5.	Enter S-Graph proportions (decim	al)	
		Valley: Developed Foothill Mountain Valley: Undeveloped	
6.	Enter maximum loss rate, F _m (in	ch/hour)	
7.	Enter low loss fraction, \overline{Y} (decimal	al)	
8.	Enter watershed area-averaged 5 (inches)*	-minute point rainfall	
	Enter watershed area-averaged fall (inches)*	30-minute point rain-	
	Enter watershed area-averaged (inches)*	l-hour point rainfall	
	Enter watershed area-averaged (inches) *	3-hour point rainfall	
	Enter watershed area-averaged (inches)*	6-hour point rainfall	junca kan
	Enter watershed area-averaged (inches)*	24-hour point rainfall	
9.	Enter 24-hour storm unit interval	(minutes)	

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E-21

E.11. INSTRUCTIONS FOR SYNTHETIC UNIT HYDROGRAPH METHOD HYDROLOGY CALCULATIONS

I. Synthetic Unit Hydrograph Development

- A. On a USGS topographic quadrangle sheet or other topographic map of suitable scale, outline the watershed boundary.
- B. Calculate the catchment time of concentration (Tc) by using either a rational method analysis for the T-year storm, or by using the peak flowrate curves of section L.
 - 1. Catchment lag is computed by

$$lag = 0.8Tc$$

2. For certain large scale natural condition catchment studies, the Agency may use the lag relationship given by

lag (hours) =
$$24\overline{n}(L \cdot L_{ca}/S^{0.50})^{0.38}$$

where

A = drainage area (square miles)

L = length of longest watercourse (miles)

L_{Ca} = length along the longest watercourse, measured upstream to a point opposite the centroid of the area (miles)

H = difference in elevation between the concentration point and the most remote point of the basin (feet)

S = overall slope of longest watercourse between headwaters and concentration point (S = H/L, feet per mile)

n = visually estimated average basin factor from Figure E2.

- C. Select a unit time period. To adequately define the unit hydrograph the unit time period should be about 20 percent of lag time, and never more than 25 percent of lag time. If possible, use the unit time of the synthetic critical storm pattern of 5-minutes.
- D. Select the S-graph applicable to the drainage basin (Figures E-3a,b,c,d). Determine the average percentage of the ultimate

discharge for each unit period. In reading the percentage of ultimate discharge from the S-graph, the <u>average</u> ordinate over the time increment should be determined rather than the mean of the ordinates at the beginning and end of the time increment (see example problem).

- E. Compute the unit distribution graph by subtracting from the percentage of ultimate discharge for each unit time period, the percentage of ultimate discharge for the previous time period.
- F. Compute the ordinates of the synthetic unit hydrograph (unit graph) by multiplying the distribution graph values by the ultimate discharge K, using:

$$K (cfs) = 645A/T$$

where

A = drainage area (square miles)
T = unit time period (hours)

II. T-Year Design Storm Pattern Development

- A. Using the appropriate T-year point precipitation values from Table B.2, compute the area-averaged precipitation values for the 5-minute, 30-minute, 1-hour, 3-hour, 6-hour, and 24-hour durations.
- B. Adjust all point precipitation values for areal effect by using Figure B-6.
- C. Develop a synthetic critical storm peak rainfall mass plot using Figure B-7 (see example problem for demonstration).
- D. Using the unit interval duration for the unit hydrograph development, calculate the synthetic storm unit interval rainfall quantities by successive subtraction of mass peak rainfall values, each offset in time by one unit period.
- E. Arrange the unit rainfall quantities determined in step D into the critical storm pattern shown in Figures B-5a,b,c. For most hydrology studies, only the peak 3-hours of the synthetic critical storm may need consideration.

III. Runoff Hydrograph Development

A. Find the pervious area loss rates for subareas within the drainage area using Figures C-3 and C-4. Adjust these rates to account for

impervious area using the relationship below, and then compute an area-averaged maximum loss rate for the catchment.

$$F_m = a_p F_p$$

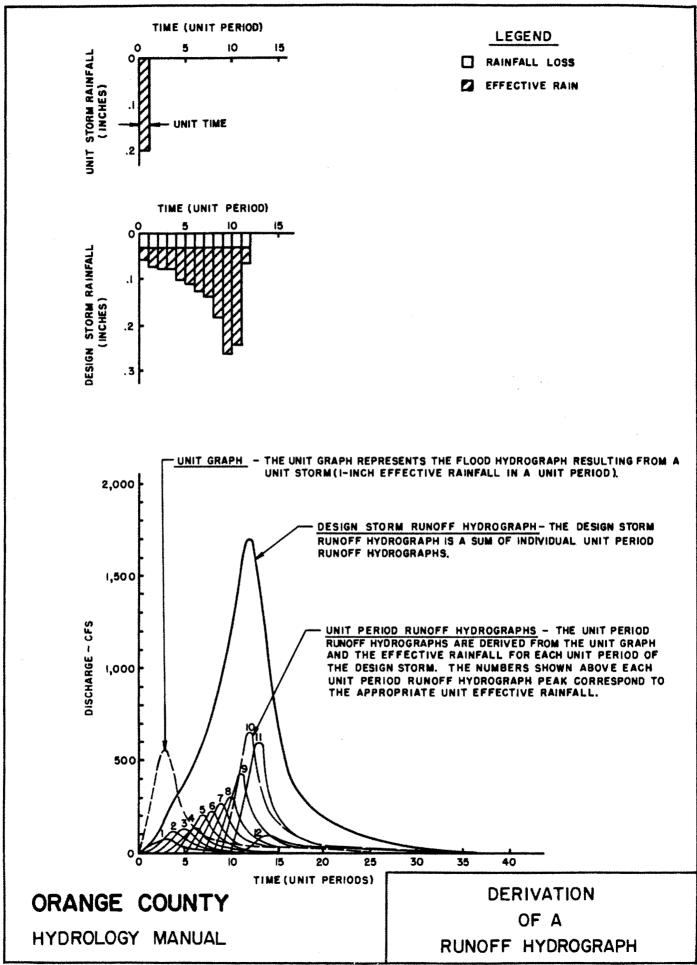
where

 $F_m = maximum loss rate (inches/hour)$

a_p = pervious area fraction (decimal percent of total area). See Figure C-4.

F_p = maximum loss rate for pervious areas fraction. See Section C.6.4.

- B. Compute the low loss fraction, \overline{Y} . Use F* in each unit time period where the maximum loss rate F_m exceeds the low loss rate F*, $(F*=\overline{Y}\cdot I)$, see Section C.6.3).
- C. Compute the unit effective rainfall for each unit time period by subtracting the unit loss from the unit rainfall.
- D. Compute the flood hydrograph.
 - 1. Multiply the effective unit rainfall for the first unit time period by each synthetic unit hydrograph value to determine the flood hydrograph which would result from that rainfall increment.
 - Repeat the above process for each succeeding effective rainfall value, advancing the resultant flood hydrographs one unit time period for each computation cycle. See Figure E-7.
 - 3. Sum the flow ordinates found in the steps above to determine the average flow ordinate per unit time period for the design storm flood hydrograph.
- E. Add the appropriate base flow to the flood hydrograph ordinates determined in Step D.

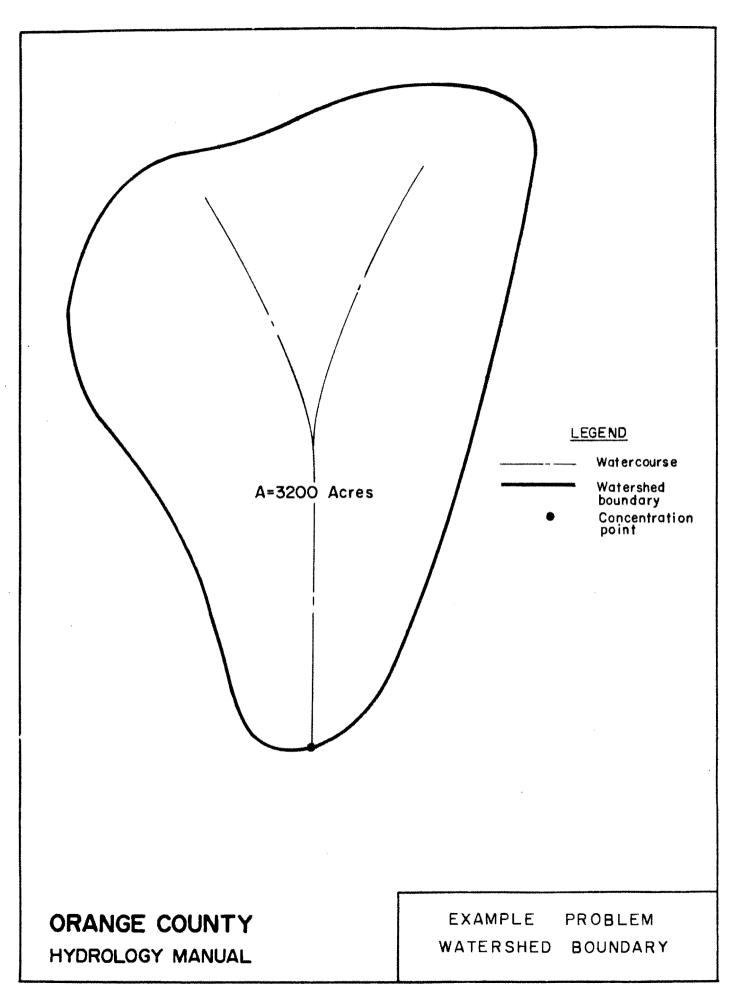


E.12. EXAMPLE PROBLEM

The following example problem illustrates the format suggested for synthetic unit hydrograph hydrology studies to be submitted for review. Additional and expanded examples are contained in the Hydrology Manual Workbook which can be obtained separately from the Agency. In the following, an example watershed is analyzed using the Agency unit hydrograph approach. The example problem presentation contains the following information:

Description

- o Watershed Map including Boundary and Geometric Information
- o Watershed Information Form
- o Adjusted and Unadjusted Mass Rainfall Plots (Depth-Area Effects)
- o 24-Hour Storm Unit Rainfall Determination (30-Minute Unit Interval)
- o Watershed-Loss Information Map
- o Area-Averaged Maximum Loss Rate (F_m) Determination
- o Area-Averaged Low Loss Fraction (Y) Determination
- o Effective Rainfall Determination
- o 24-Hour Critical Storm
- o S-Graph Approximation
- o Unit Hydrograph Determination
- o Runoff Hydrograph Determination
- o Runoff Hydrograph

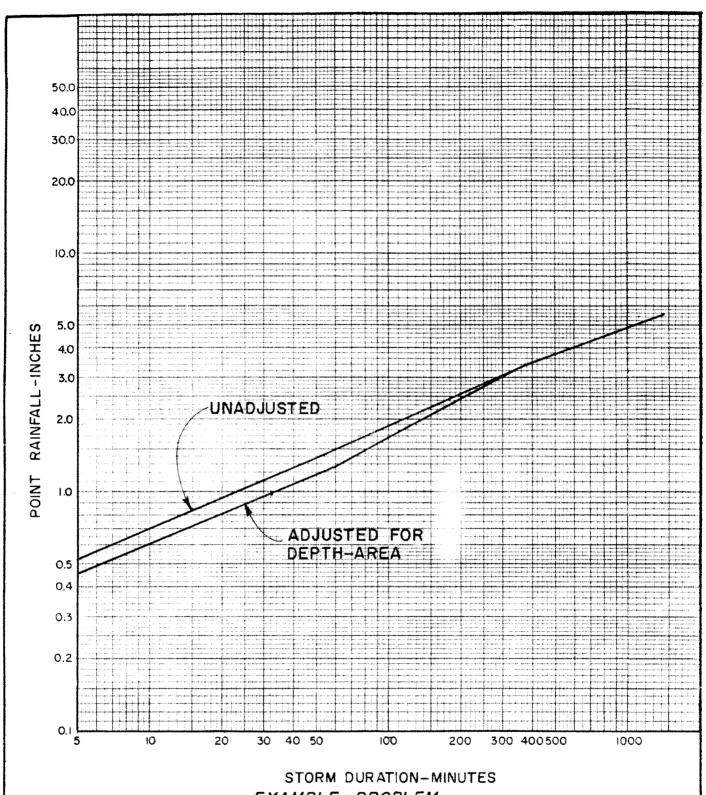


PROJECT:		EXAMPLE PROBL	DATE:	
ENG	INEER:			
1.	Enter	the design storm return	frequency (years)	100
2.	Enter	catchment lag (hours)		0.75
3.	Enter	the catchment area (acr	res)	3200
4.	Enter	baseflow (cfs/square mi	le)	
5.	Enter	S-Graph proportions (de	cimal)	
			Valley: Developed Foothill Mountain Valley: Undeveloped	1.0 0.0 0.0 0.0
6.	Enter	maximum loss rate, F _m	(inch/hour)	0.19
7.	Enter	low loss fraction, \overline{Y} (dec	cimal)	<u>0.337</u>
8.	Enter (inche		ed 5-minute point rainfall	0.52
		watershed area-averag nches)*	ed 30-minute point rain-	1.09
	Enter (inche		ged l-hour point rainfall	1.45
	Enter (inche		ged 3-hour point rainfall	2.43
	Enter (inche		ged 6-hour point rainfall	<u> 3.36 </u>
	Enter (inche		ed 24-hour point rainfall	<i>5.63</i>
9.	Enter	24-hour storm unit inter	rval (minutes)	5.0

^{*}Note: enter values <u>unadjusted</u> by depth-area factors

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PROJECT LOCATION EXAMPLE PROBLEM

NOTES 100-YEAR STORM

ORANGE COUNTY HYDROLOGY MANUAL

AREA - AVERAGED MASS RAINFALL PLOTTING SHEET

UNIT HYDROGRAPH STUDY: EXAMPLE PROBLEM UNIT RAINFALL DETERMINATION

(Example Unit Period = 5 minutes)

Peak Rainfall Unit Number	Adjusted Mass Rainfall (inches)		it Rainfall (inches)
1	0.45		0.45
2	0.60		0.15
3	0.71		0.11
Įţ.	0.80		0.09
5	0.88		0.08
6	0.95		0.07
7	1.02		0.07
8	1.08		0.06
9	1.13		0.05
10	1.19		0.06
11	1.24		0.05
12	1.28		0.04
13	1.33		0.05
14	1.39		0.05
15	1.45		0.06
16	1.50		0.05
17	1.55		0.05
18	1.60		0.05
19	1.65		0.05
20	1.70		0.05
21	1.74		0.04
22	1.79		0.05
23	1.84		0.05
24	1.89		0.05
25	1.93		0.04
26	1.97		0.04
27	2.01		0.04
28	2.05		0.04
29	2.09		0.04
30	2.13		0.04
31	2.17		0.04
32	2.21		0.04
33	2.25		0.04
34	2.29		0.04
35	2.33		0.04
<u>36</u>	2 38		0.04
TIME = 3 HOURS		TOTAL =	2.38 INCHES

UNIT HYDROGRAPH STUDY: EXAMPLE PROBLEM WATERSHED LOSS DETERMINATIONS

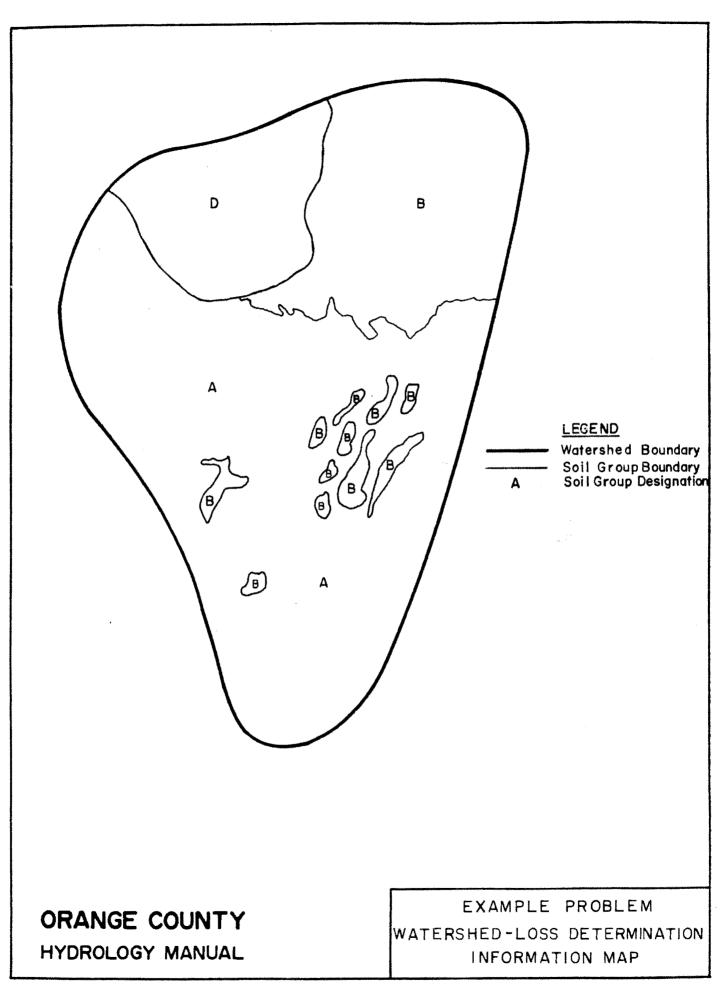
Area-Averaged Maximum Loss Rate, F_m

1. Using the watershed soil and development characteristics, estimate the area-averaged maximum loss rate:

Land Use and Condition	Area Fraction	Soil Group	F _p (inch/hour) (Table C.2.)	(Fig. C-4)	F _m (inch/hour)
Woodland; good cover (100% pervious)	.15	В	0.30	1.0	0.30
Woodland; good cover (100% pervious)	.15	D	0.20	1.0	0.20
Residential:S.F. (1/2 acre) Lots (60% pervious*)	. 42	А	0 - 40	0.60	0.24
Residential:S.F. (1/2 acre) Lots (60% pervious*)	.03	В	0.30	0.60	0.18
Commercial: (10% pervious)	.23	A	0.40	0.10	0.04
Commercial: (10% pervious)	.02	В	0.30	0.10	0.03

Area-Averaged Adjusted Loss Rate (inch/hour) = 0.19

^{*} Field conditions indicate use of the lower end of the suggested percent pervious range.



UNIT HYDROGRAPH STUDY: EXAMPLE PROBLEM WATERSHED LOSS DETERMINATIONS

Area-Averaged Low Loss Rate Fraction, Y

1. Referring to watershed soil group maps, estimate area-averaged composite curve numbers (see Section C):

Land Use and Condition	Area Fraction	Soil Group	Curve Number CN(1) (Fig. C-3)	_S (2)	Pervious Area Yield Fraction Y(3)
Woodland; good cover (100% pervious)	.15	В	55 (75)	3.33	0.53
Woodland; good cover (100% pervious)	.15	D	77 (93)	0.75	0.86
Residential: S.F. (1/2 acre) Lots (60% pervious)(5)	.25 .17	A A	32 (52) 98	9.23 0.20	0.20 0.96
Residential: S.F. (1/2 acre) Lots (60% pervious)(5)	.018	B B	56 (76) 98	3.16 0.20	0.54 0.96
Commercial: (10% pervious)	.023	A A	32 (52) 98	9.23 0.20	0.20 0.96
Commercial: (10% pervious)	.002	В В	56 (76) 98	3.16 0.20	0.54 0.96

Area-Averaged Catchment Yield Fraction (Y) = 0.663

Area-Averaged Low Loss Fraction $(\overline{Y})^{(4)} = 0.337$

NOTES:

- (1): (75) indicates AMC III CN (Table C.1)
- (2): S = (1000/CN)-10
- (3): $Y = (P24-0.2S)^2/((P24+0.8S)P24)$
- (4): $\overline{Y} = 1 Y$
- (5): Field conditions indicate use of the lower end of the suggested pervious range

UNIT HYDROGRAPH STUDY: EXAMPLE PROBLEM 3-HOUR STORM EFFECTIVE RAINFALL DETERMINATION

(Example Unit Period = 5 minutes)

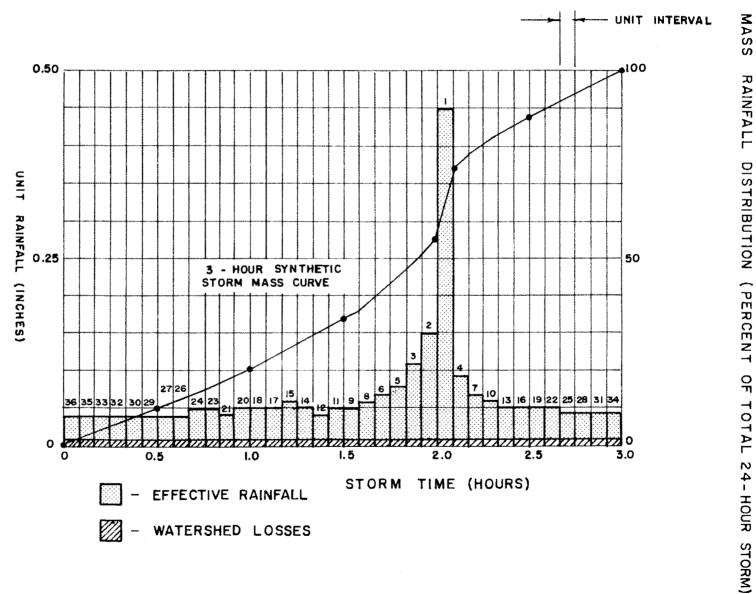
Unit Period Number	Unit Rainfall (inches)	Unit Loss (inches)	Effective Rainfall (inches)
Number 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17	.04 .04 .04 .04 .04 .04 .05 .05 .05 .05 .05	.013 .013 .013 .014 .014 .015 .015 .015 .016 * .016 * .016 * .016 *	.025 .026 .026 .027 .027 .028 .029 .029 .030 .031 .029 .034 .036 .037 .040 .042
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36	.05 .05 .06 .07 .08 .11 .15 .45 .09 .07 .06 .05 .05 .05 .05	.016 * .017 * .018 * .019 * .0	.031 .037 .042 .053 .062 .094 .135 .438 .074 .054 .034 .044 .039 .035 .032 .030 .028 .027 .026

^{*}Unit low loss exceeds unit adjusted loss

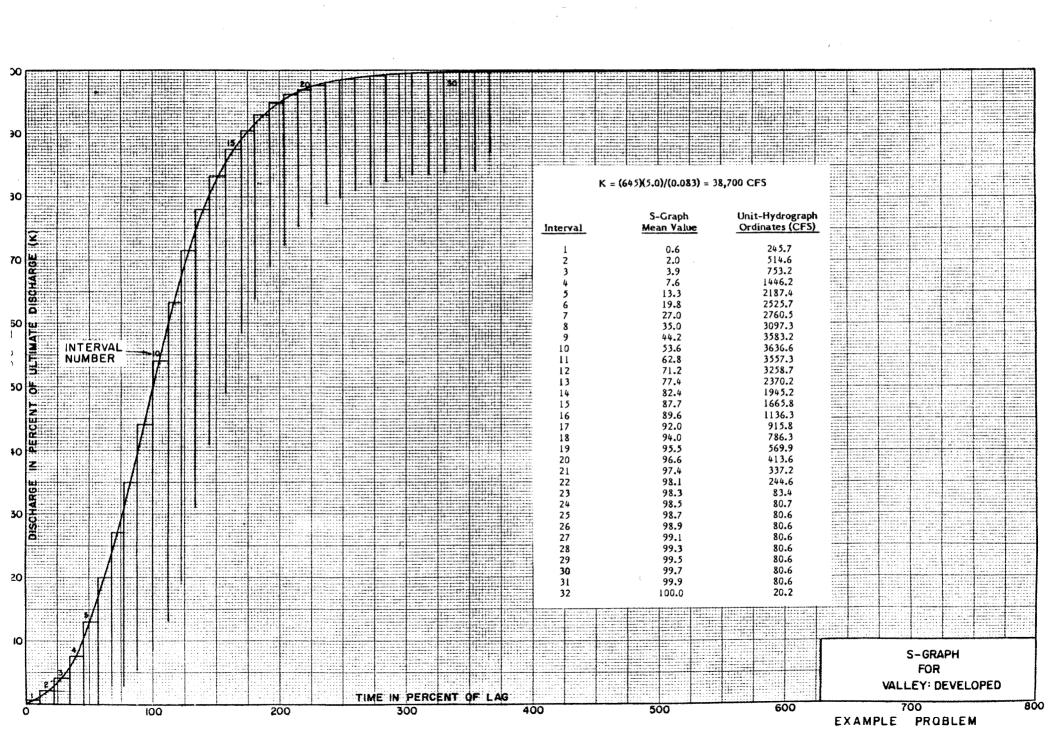
NOTE: THE EXAMPLE UNIT INTERVAL = 5 MINUTES.

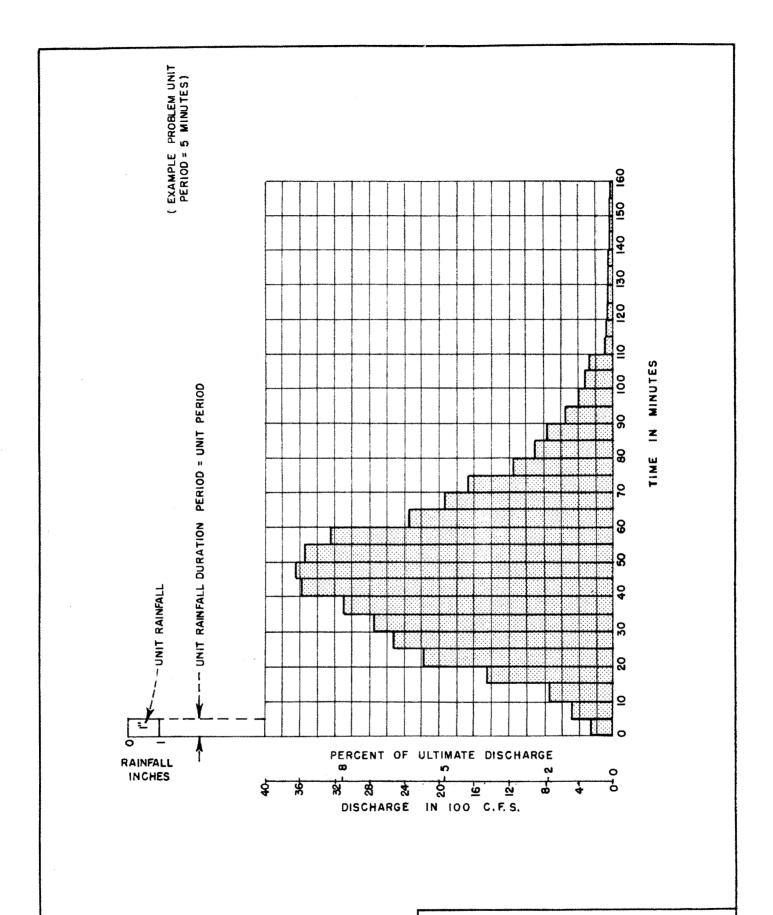
NUMBERS ABOVE UNIT RAINFALLS CORRESPOND

TO UNIT NUMBERS IN UNIT RAINFALL DETERMINATION.



EXAMPLE
SYNTHETIC 3-HOUR
CRITICAL STORM





ORANGE COUNTY
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EXAMPLE PROBLEM

UNIT DISTRIBUTION GRAPH

ORA	NG	E C	OUN	ITY			SYNT	HET	ic u	NIT	HYDI	ROGF	APH	ME	тно	D		Proj	ect _I	XA	MP	LE	PR	⊃ ₽ .(ЕM	_ \s	heet	7
HYC	ROLO	OGY I	Man	UAL			F	1004	Hydi	rogra	ph C	alcul	ation	For	m				TR	W H	5		ate				/2	2
\boxtimes	EFFEC RAIN (in)	.025	.0eL	026	.027	.027	.028	029	.0 29	.050	. <i>0</i> 31	.029	.034	.036	. <i>0</i> 37	040	.042	.029	.0 3 1	.037	.042	<i>.0</i> 53	.062	.094	.135	FLOOD HYDRO-	BASE-	DESIGN FLOOD
UNIT	UNIT	ı	2	3	4	5	b	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	GRAPH (cfs)	FLOW (afe)	HYDRO- BRAPH (cfs)
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753	3	19	15	ے																						40	50	70 90
2187	5	36 55	38	15 20	7 16	7																				78 136	50 50	128
2526 2761	7	63 69	57 66	38 57	<u>20</u>	20	7 16	7																		201 274	<u>50</u>	<u> 251</u> 324
3097 3583	9	77 90	72 81	72	59 48	3 <i>9</i> 59	21 40	17 22	7	7							······································									358 456	50 50	408 506
3637 3557	10	9 ₁		93 93	75 84	68 75	61 71	42 63	22 42	17 23	8 18	7														558 660	50 50	608 710
32 <i>59</i> 23 <i>7</i> 0	13	8) 59	92 85	95 92	97 98	84 97	77 87	73 80	63 73	43 66	23 45	17 22	20	9												753 833	50 50	803 883
1945	15	49	62 51	85 62	96 88	98	100	<i>9</i> 0	8 0	76 83	68 78	42 63	26 49	21	<i>9</i>	10										902 966	50	952 1016
1136	16 17	28 23	43 30	51 43	64 53	88 64	100 91	105	164	93 107	86 96	73 80	7 4 86	52 79	<i>28</i> 54	23 30	10 24	7								1022	50 50	1072 1125
78G 570	18	20 14	24 20	30 24	45 31	53 45	66 54		103 95	-	111	90	94	91 99	81 93	58 87	32 61	17	8 18	9						1127	50 50	1177
44	20 21	10	15	20	25 21	31	47 32	56 48	69 56	<i>98</i>	110	105	122	111	10Z	101	92	42	23 45	21	10	1.3				1210	50	126
Z45 83	22	6	9	ر. اا و	15	21	26 22	33 27	48 33	58 50	73 60	95 69	121	131	133	124	116	73 80	48 78	54	32	30	15 36	23		1292	50	1342 1900
81	24 25	2	2	6 Z	9 7	11	16	23	27 23	34 27	<i>52</i>	56	81	117	132	145	150	_	86	93	92	77	47 90	54 71	3 <u>3</u>			H84
81	26	2	2 Z	Z	2	7	9	12	17	24 17	28	33	57	70	88	130	149	105	111	115	116	134	136	136	501			
81	27	2	2	2	2 2	2	2.	10	10	12	18	23	39	41	72 62		137	95	***	133	150	164		206 237	295			
81	30		2 Z	2	2	2	2	Z Z	7 2	10 7	13	17	19	33 28	42 34	67 45	8Z 70	69 56	73	121	149	193	222	291	373		<u> </u>	
20	31 32	1	2	2 <u>.</u> 2	2	2	2	2	2 Z	2 2	7 3	7	14	15	29	37 31	4 <u>8</u> 3 <u>8</u>	48	60 52	72	137	173	ZZI	337 34Z				
				2	2	2	2	2	2	2 Z	3	2	3	12	12	23 17	24	27	35 28	62 42	70	103			491			
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															1	3	<u>3</u> 3	2 2	3	3	3 3	4 4 4	5	8	33			
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SECTION F

FLOW-THROUGH BASIN ANALYSIS

F.I. INTRODUCTION

There are two types of routing that are important in watershed planning; reservoir routing and streamflow routing. Both processes operate upon an inflow hydrograph to produce an outflow hydrograph. In this section, reservoir routing will be presented based on the modified Pul's method. Section H will present the convex method for streamflow routing. It should be noted that the Agency has hydraulic design criteria which must be considered in addition to the hydrologic criteria established in this manual.

Section E of this hydrology manual includes a detailed discussion of the unit hydrograph approach to be used for hydrologic studies of watersheds. Section B.5 presents a discussion on the appropriate design storm for watershed with flow-through detention basins.

For a discussion on the use of detention basins see Appendix IV.

F.2. DETENTION BASIN ANALYSIS

F.2.1. Detention Basin Routing Procedure

The modified Pul's (refs. 2, 3, 5) method may be used for detention basin routing studies. The basin routing relationships are based upon the formula

$$I - O = \frac{\Delta S}{\Delta t}$$
 (F.1)

where

I = basin inflow rate (cfs)

O = basin outflow rate (cfs)

 ΔS = change in basin storage during the time step (cubic

feet)

 $\Delta t = time step (sec)$

Equation (F.1) is approximated by replacing the variables I and O by an average value during the timestep using

$$I = \frac{I_1 + I_2}{2} \tag{F.2}$$

$$O = \frac{O_1 + O_2}{2} \tag{F.3}$$

where the subscript 1 indicates the beginning of a time period and subscript 2 indicates the end of the subject time period. Substituting (F.2) and (F.3) into the basin routing equation of (F.1) and rearranging terms gives

In (F.4), the right side is known from the previously computed values of storage, S_1 , outflow, O_1 , and the average basin inflow $(I_1+I_2)/2$ for time step Δt .

The solution of the basin routing problem requires the following information:

- 1. Known initial conditions for basin storage and outflow
- 2. A routing timestep, Δt
- 3. The basin inflow hydrograph
- 4. Basin volume vs. depth and outflow vs. depth relationships

To solve (F.4), a storage indication curve should be developed. Such a curve may be derived from the known storage-discharge relationship by selecting

various values of depth and computing (S+O $\Delta t/2$) from the associated values for storage and outflow. This quantity is plotted versus outflow such as shown in Figure F-4.

The solution procedure then proceeds with the following steps:

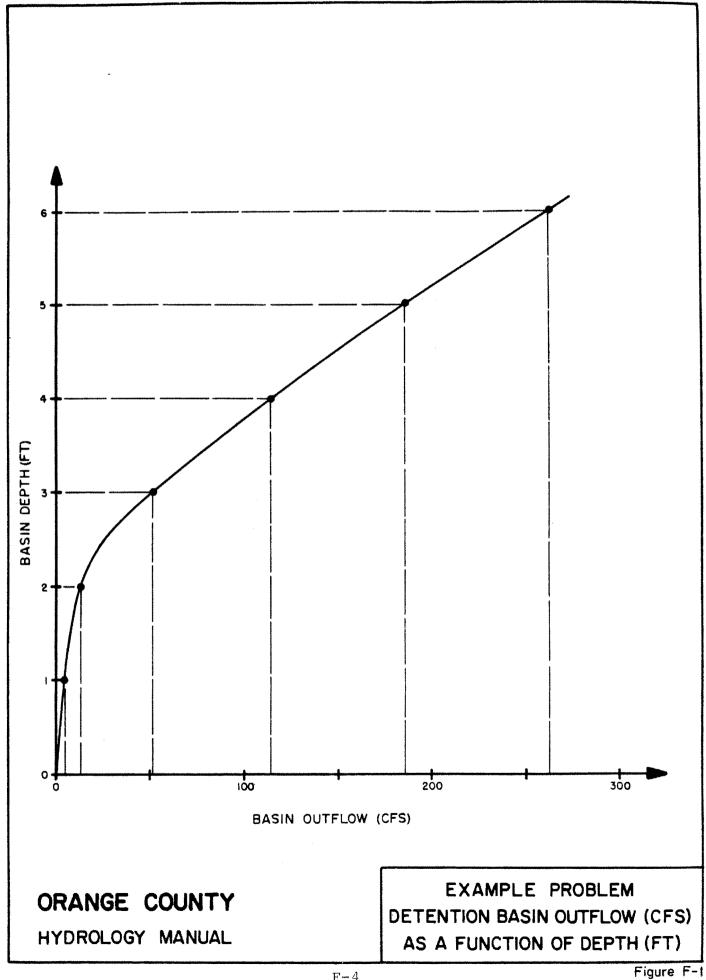
- 1. Determine the average inflow volume from the inflow hydrograph during the timestep Δt ; i.e., calculate $(I_1 + I_2) \Delta t/2$.
- 2. Compute $S_1 O_1 \Delta t/2$ from the assumed initial condition of the basin flowdepth or the last computed values of S and O.
- 3. Use (F.4) to compute ($S_2 + O_2 \Delta t/2$).
- 4. Use the estimate from step 3 and the storage indication curve (see Figure F-4) to compute O_2 .
- 5. Use O_2 and the known storage vs. depth and outflow vs. depth relationships to compute S_2 .

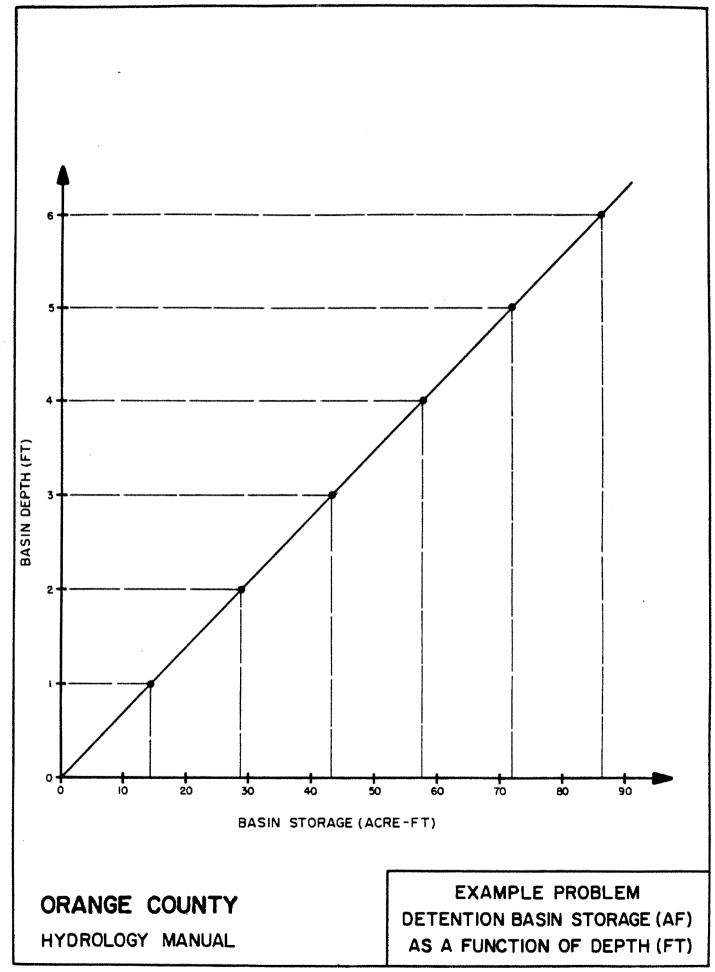
These five steps are repeated for the next timestep using I_2 , O_2 , and S_2 as the new values of I_1 , O_1 , and S_1 , respectively. This procedure is repeated until the basin inflow hydrograph has been completely analyzed and basin outflow becomes negligible.

The example problem illustrates the basin routing procedure.

F.2.2. Example Problem: Detention Basin Hydrograph Routing

The assumed detention basin depth vs. outflow and depth vs. storage relationships are shown in Figures F-1 and F-2, respectively. The detention basin information sheet (Figure F-8) is completed in Figure F-3. Using a timestep of 60 minutes (3600 seconds), the associated storage-indication curve is developed in the following table and plotted in Figure F-4.





PRO	JECT:	EXAMPLE	PROBLEM	DATE:	
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1.	Enter	the hydrograph un	it interval duratio	on (minutes)	60
2.		total number of (maximum of 20)		ersus-outflow	7
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	1	100	0.0 (defin	ned)	0.0 (define
	2	101		14.4	4.2
	3	102	2	28.8	120
	4	103	3	43.2	51.7
	5	104	4	57.6	114.7
	6	105	5	72.0	186.8
	7	106	6	86.4	263.2
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Figure F-3

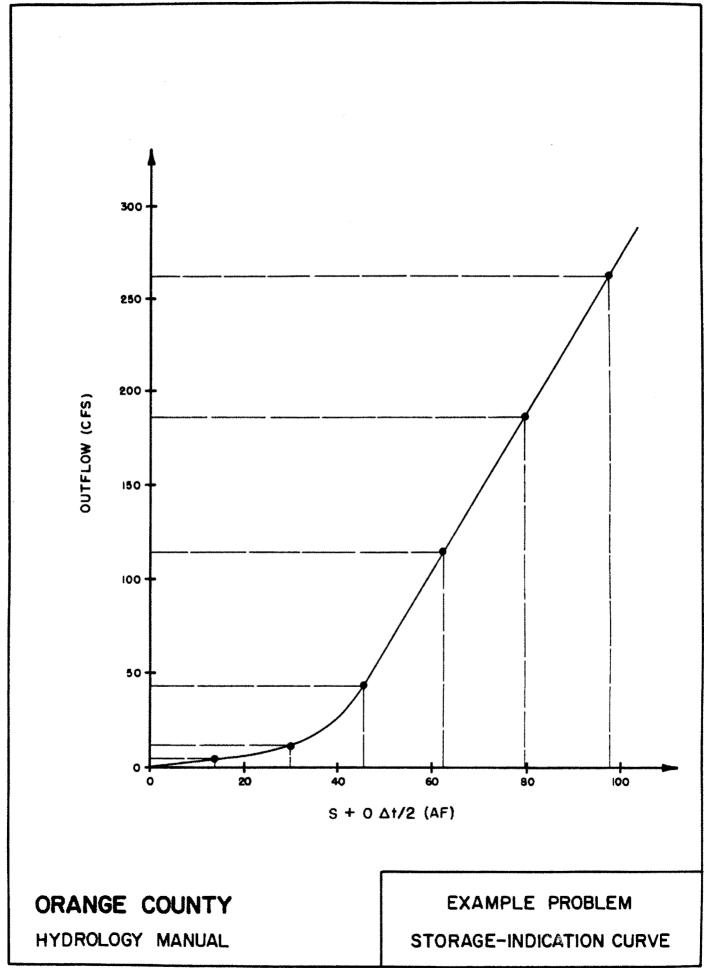


TABLE F.1.

EXAMPLE PROBLEM STORAGE-INDICATION CURVE DEVELOPMENT

Depth (ft)	O (cfs)	S <u>(AF)</u>	$S-O \Delta t/2$ (AF)	S+O $\Delta t/2$ (AF)
0	0	0	0	0.0
1	4.2	14.4	14.22	14.57
2	12.0	28.8	28.30	29.30
3	51.7	43.2	41.06	45.34
4	114.7	57.6	52.86	62.34
5	186.8	72.0	64.28	79.72
6	263.2	86.4	75.52	97.28

Assuming an initial condition of zero basin outflow and storage, an example basin inflow hydrograph (unit period of 60 minutes) is routed using the modified Pul's method in the tabulation of Table F.2. The 60-minute timestep is used for demonstration purposes only. Typically, a 5-minute timestep is needed in order to adequately describe the runoff hydrograph peak flow rates. Important features of a routed detention basin hydrograph are shown in Figure F-5.

F.3. REQUIRED FORMAT

Figure F-6 illustrates the required format for submitting detention basin study results for review.

Figure F-7 is to be used to supply the necessary detention basin information to determine the routing results.

TABLE F.2. EXAMPLE PROBLEM BASIN ROUTING TABULATION

Time (min.)	Inflow (cfs)	Average Inflow (cfs)	$\begin{array}{c} (\mathbf{I_1} + \mathbf{I_2}) \Delta \mathbf{t/2} \\ \underline{(\mathbf{AF})} \end{array}$	S_1 -O ₁ $\Delta t/2$ (AF)	S ₂ +O ₂ ∆t/2 (<u>(AF)</u>	Outflow (cfs)	Storage (AF)
0	0					0	0
		30	2.48	0	2.48		
60	60					.7	2.45
120	1.20	90	7.44	2.42	9.86	2.0	0.76
120	120	200	16.53	9.62	26.16	2.8	9.74
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		265	21.90	25.31	47.21		
240	250					58.6	44.79
		235	19.42	42.37	61.79		
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		80	6.61	54.41	61.02		
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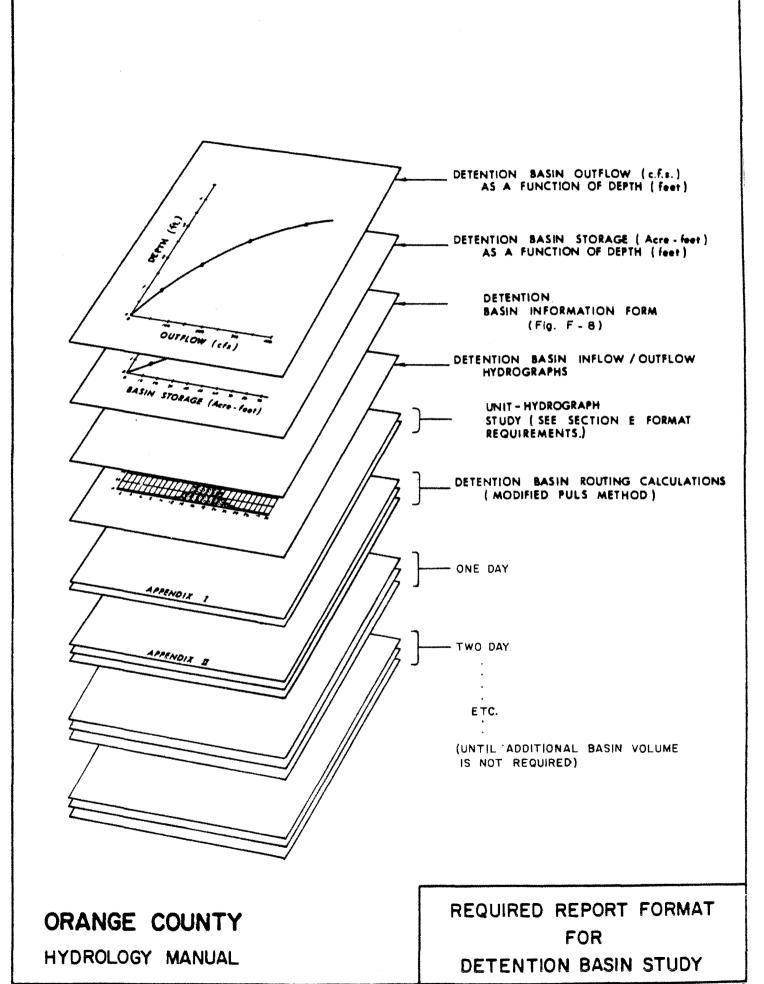


Figure F-6

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ORANGE COUNTY
HYDROLOGY MANUAL

DETENTION BASIN INFORMATION FORM

SECTION G

FLOW-BY BASIN ANALYSIS (HYDROGRAPH SEPARATION)

G.I. INTRODUCTION

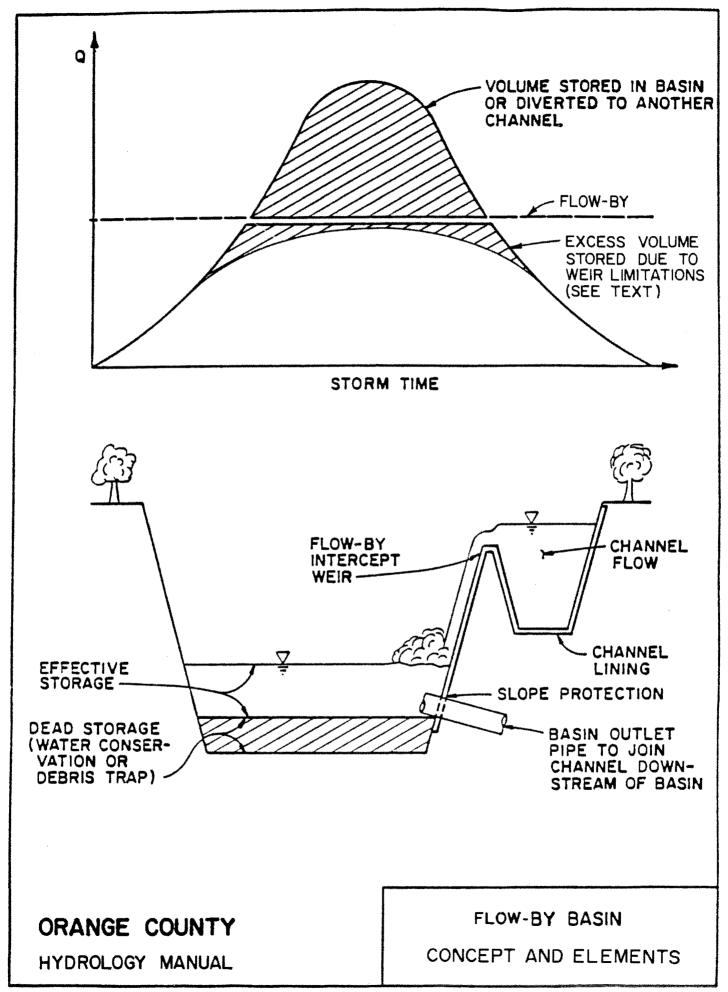
This process models the effect of a channel flowing by a detention basin or structure which intercepts and diverts away from the channel all runoff flows in excess of some specified flowrate. Although simple in concept, use of a flow-by basin in a flood control system can provide a useful reduction in the runoff hydrograph peak flowrate. Figure G-I shows the main elements of a typical flow-by basin.

G.2. EXTENDED DESIGN STORM CRITERIA

A multiple day storm may be required to guarantee that the basin has an adequate storage capacity remaining when a peak 24-hour storm event occurs. For a multiple day storm condition involving a flow-by basin system, the peak rainfall intensities of the selected T-year return frequency should be incorporated within each 24 hour duration (up to the appropriate mass rainfall volume with the desired return frequency). A detailed discussion of the design for watersheds with flow-by basins is presented in Section B.6.

G.3. FLOW-BY BASIN VOLUME ANALYSIS: WEIR STRUCTURE EFFICIENCY

Figure G-I illustrates a typical weir structure flow-by basin design. Due to the finite weir length, the actual flow-by discharge (i.e., no overflow into the basin) is less than the desired flow-by discharge and, consequently, the actual basin storage requirements are higher than idealized by a simple separation of the hydrograph. Generally, this volume excess ranges between 20 and 50 percent depending on the weir length used for the overflow.



SECTION H

STREAMFLOW ROUTING

H.I. INTRODUCTION

Although a calibrated peak discharge is obtained when using the unit hydrograph method applied to a single area, there are instances where a runoff hydrograph must be routed through a stream or channel. There are three common situations where streamflow routing is required: (1) downstream of a detention basin, (2) when the watershed has a "finger" or other non-elliptical shape such as an hour-glass shape, and (3) significant inhomogeneity of ultimate land use or soil type within the watershed.

The convex routing technique (refs. 2, 3) shall be used whenever streamflow routing is necessary; however, the Agency may accept some other routing techniques such as Muskingum Routing only if the results are comparable to those obtained by convex routing.

H.2. CONVEX ROUTING METHOD FOR UNSTEADY OPEN CHANNEL FLOW

The governing relationship used in the convex routing approach is:

$$O_{T+dT} = (1-C)O_T + CI_T$$
 (H.1)

where

I_T = hydrograph inflow at time T

 O_T = channel outflow at time T

 O_{T+dT} = channel outflow at time T + dT

C = a routing coefficient (where C is between 0 and 1)

Rearranging (H.1) gives the explicit statement

$$O_{T+dT} = O_T + C(I_T - O_T)$$
 (H.2)

and

$$C = (O_{T+dT} - O_T)/(I_T - O_T)$$
 (H.3)

The routing coefficient may be estimated by the empirical relationship (ref. 3),

$$C = V/(V + 1.7) \tag{H.4}$$

where V is a mean flow velocity assumed for the inflow hydrograph. One method of computing V is to calculate the normal depth corresponding to the average flowrate of all unit flows greater than 50 percent of the inflow hydrograph peak flowrate. From this normal depth calculation, V is defined to be the corresponding flow velocity. Thus V represents an average velocity which is used to translate the inflow hydrograph along the total length of the channel. Obviously, other values for V can result depending on the choice of the average flowrate value from the inflow hydrograph, and care must be taken to avoid offsetting the hydrograph peak flowrates at channel confluences by the selection of the channel V parameter.

The routing timestep, dT, is given by

$$dT = \frac{CL}{3600 \text{ V}} \tag{H.5}$$

where C is given by (H.4), L is the channel length in feet, and dT is in units of hours.

Because the unit hydrograph analysis base unit period dT* is usually different than the dT time period of (H.1) a modification of C is required. For a unit period of 5 minutes, dT* = 0.0833 hours and the modified routing coefficient is

$$C* = 1 - (1-C)^{E}$$
 (H.6)

where

$$E = (dT* + 0.5dT)/(1.5dT)$$

To determine the dT which corresponds to (H.1), it is assumed that

$$(O_{T+dT} - O_T)/(I_T - O_T) = dT/K$$
 (H.7)

where K is the channel reach travel time as estimated from the selection of the inflow hydrograph mean V value and the channel length, L. Figure (H-1) illustrates the geometric interpretation of the relationship given by (H.7). Thus,

$$dT = CK$$
 (H.8)

A 5-minute unit period is used for all convex routing applications.

An examination of the convex routing method reveals that the entire routing approach is a function of the routing coefficient, C. Consequently, a watershed link-node model composed of m such channel links necessarily includes m channel routing parameters, each with an associated unknown uncertainty function. Additionally, the uncertainty involved in combining the m channel links is further aggravated by the fact that each channel-routed hydrograph is also a function of the number and channel reach lengths used for each channel link. That is, the routed hydrograph through a channel with

a length of 20,000 feet will differ from the results of routing a hydrograph through two successive reaches with a length of 10,000 feet, and so forth. Channel routing processes usually involve relatively short reaches of improved channel where storage effects are minor, or where confluences from other channels (or pipes) enter the main channel and a summation of hydrographs occurs. Finally, the routing coefficient is a function of the calculation timestep. The example problem demonstrates the variation in C due to the calculation timestep used.

H.2.1. Example Problem: Convex Channel Routing

The example problem channel is a rectangular concrete section with a base of 10 feet, a Manning friction factor of 0.015, length of 3000 feet, and a mean slope of 0.005 foot/foot. The problem inflow hydrograph is tabulated in Table H.1. From the table, the average flowrate in excess of the 50-percent peak flowrate value is 767.4 cfs.

Using Manning's equation, the normal depth flow velocity is calculated as

$$V = (1.486R_h^{0.67}S_0^{0.50})/n \tag{H.9}$$

where R_h is the hydraulic radius, and S_0 is the channel slope. For the example problem, V is 13.5 fps (feet per second) and the default routing coefficient from (H.4) is C = 0.89. From (H.8),

K = (3000 ft)/(13.5 fps)(3600 sec/hr) = 0.062 hour

dT = (0.89)(0.062) = 0.055 hour

From (H.5), C* is estimated for a timestep of dT* equal to 5 minutes by

$$C* = 1 - (1-0.89)^{E} = 0.948$$

where E = (0.0833 + (0.5)(0.055))/((1.5)(0.055)) = 1.343. Thus the appropriate convex method routing approximation statement is

$$O_{T+dT} = (1-C*)O_{T+dT-dT*} + C*I_{T}$$
 (H.10)

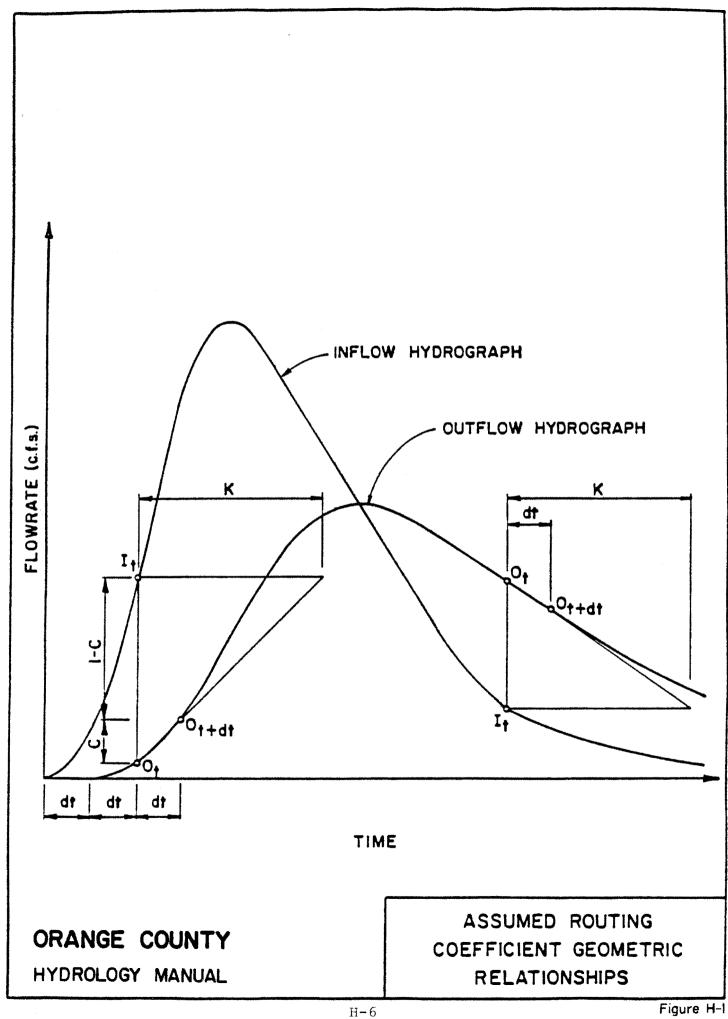
where for the example problem

$$O_{T+dT} = (0.052)O_{T+dT-dT} * + (0.948)I_{T}$$

TABLE H.I.
CONVEX ROUTING EXAMPLE PROBLEM SOLUTION

Storm Time Inflow (cfs)	Outflow ¹ (cfs)
0.0	0.0
5 0.8	0.3
10 0.9	0.8
15 40.5	7.7
20 202.7	91.1
25 445.1	274.6
30 602.9	486.8
35 653.7	613.1
40 600.9	634.7
45 608.0	605.0
50 917.1	706.9
55 1186.7	992.5
60 1001.2	1117.1
65 763.6	931.1
70 714.9	756.7

Note 1: outflow is to be offset by 3.7 minutes of travel time due to a computed mean flow velocity of 13.5 fps.

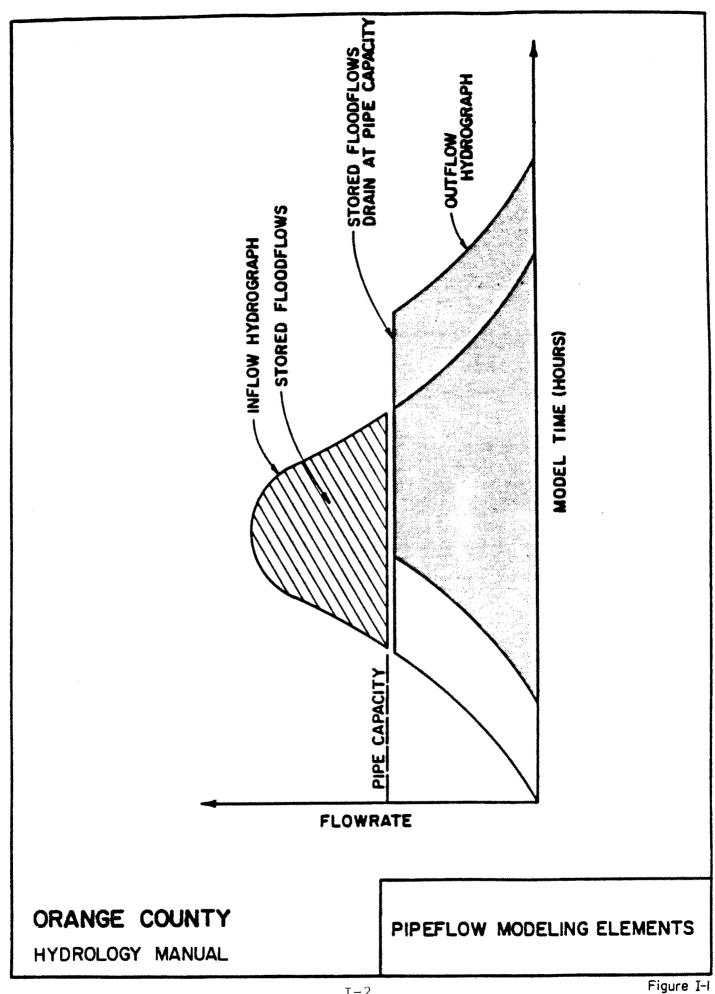


SECTION 1

A PIPEFLOW ROUTING MODEL

Similar to the convex routing approximation procedure, the pipeflow routing model develops an outflow hydrograph from a reach of pipe given an inflow hydrograph and appropriate pipe section data. In the considered pipeflow model, however, a limiting value of outflow is assumed whereby all inflows greater than this pipe capacity are temporarily stored at the upstream endpoint of the pipe. The stored floodwaters subsequently drain into the pipe at a rate equal to the pipe capacity. Where this assumption is not valid, an alternative approach should be used. This modeling approach approximates the ponding of floodwaters where a significant volume of storage is available with a small change in flooding depths. Similar to the convex channel routing method, backwater effects are not included in the modeling approach.

The pipeflow routing process is modeled by calculating a normal depth flow velocity for each unit period (e.g., 5-minute) runoff value from the inflow hydrograph, and translating the unit runoff forward in storm time by the appropriate time increment. Generally, flowdepths in excess of 0.82 of the pipe diameter are assumed to be sealed and the unit interval flow velocities are computed based on a full flow condition. Figure I-l shows the salient features of the pipeflow modeling approach.



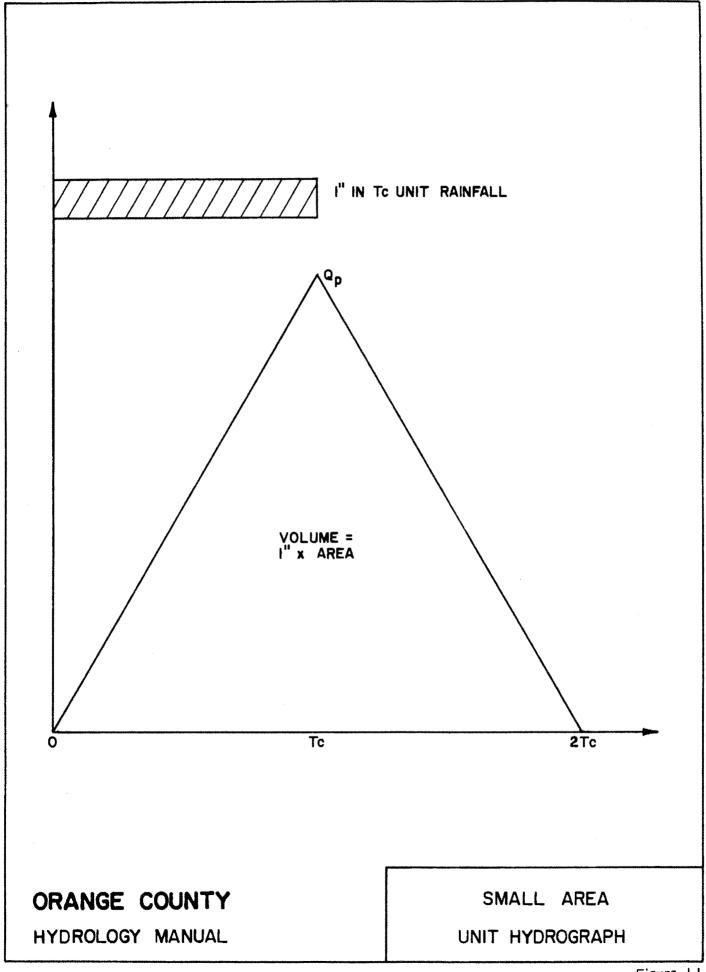
SECTION J

SMALL AREA RUNOFF HYDROGRAPH DEVELOPMENT

J.I. INTRODUCTION

For watersheds whose time of concentration (see Section D) is less than 25 minutes, a simpler procedure can be used to develop the design storm runoff hydrograph. Additionally, the 25-minute limitation corresponds to a 25-percent unit interval (of watershed lag) when using 5-minute unit rainfalls in the unit hydrograph technique. Consequently, in order to avoid the unit hydrograph being too coarse an approximation, a small-area unit hydrograph method is needed. This technique is analogous to the design storm approach of Sections B and E but has the following simplifications:

- i. <u>Depth-area Adjustment</u> Generally, watersheds whose time of concentration is less than 30 minutes have a drainage area small enough that depth-area adjustment is not required; i.e., the regionalized point rainfall depths are used without depth-area adjustment.
- ii. <u>Design Storm Pattern Development</u> Using a unit interval equal to the time of concentration (Tc), unit rainfalls are determined by successive subtractions along the mass rainfall plot (see Example).
 - iii. Loss Rates Conforms to Section E.
- iv. <u>Unit Hydrograph</u> The unit hydrograph is defined to be a triangle with a base of 2Tc, and a peak at time of Tc (see Figure J-1). The volume of the unit hydrograph is (1-inch)(area). The example problem illustrates the triangle unit hydrograph. Note that in this case, lag is defined to equal the Tc estimate; (i.e., 50-percent volume occurs at time of Tc). Also note that lag is not computed, but the rational method Tc is used directly.



v. <u>Convolution</u> - The convolution of the unit hydrograph with the unit effective rainfalls (storm rainfall less losses) is simply the addition of peak runoff values at each of the Tc unit intervals (see Example), where peak flow estimates follow from the rational method of Section D.

It is noted that in the small area runoff hydrograph method, the total catchment area shall be used in the calculations; i.e., although the effective area may be used for rational method estimates for peak flow rates, the total catchment area is needed for runoff hydrograph volume study purposes. Any deviation from the use of the total catchment area must be approved by the Agency.

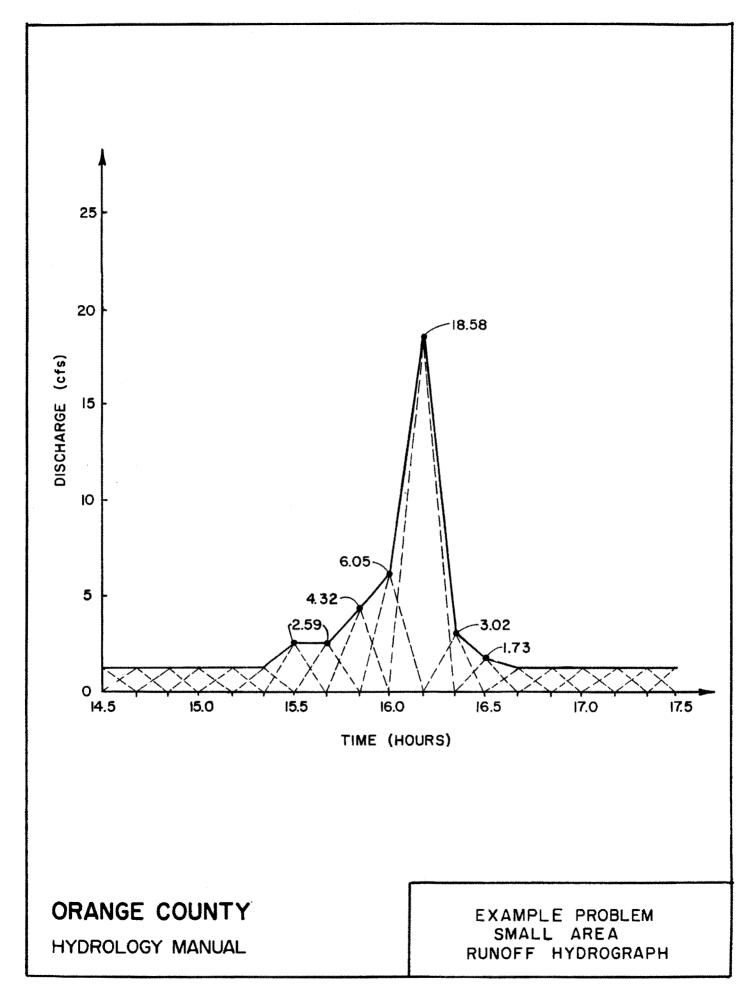
J.I.I. Example Problem: Small Area Runoff Hydrograph Development

- 1. Assume given from a rational method study (see Section D): watershed area = 8 acres time of concentration = 10 minutes = unit interval maximum loss rate (F_m) = 0.12 inches/hour low loss fraction (Y) = 0.35
- 2. $D_{10} = 0.17T^{0.427}$ (see Figure B-1) where $D_{10} = 10$ -year frequency depth (inches) T = duration (minutes)
- 3. $Q = 0.9 (I-F_m)A$

TABLE J.1. EXAMPLE PROBLEM RESULTS

Mass Rainfall (Inches)	Unit Rainfall (Inches)	Unit Loss (Inches)	Net Rainfall (Inches)	Effective Rainfall (Inch/Hr.)	Discharge (Q) (cfs)
0.45	0.45	.02*	0.43	2.58	18.58
					6.05
					4.32 3.02
					2.59
					2.59
					1.73
					1.73
1.16	0.06	.02*	0.04	.24	1.73
1.21	0.05	.02*	0.03	.18	1.30
1.27	0.06	.02*	0.04	.24	1.73
1.31	0.04	.01	0.03	.18	1.30
1.36	0.05	.02*	0.03	.18	1.30
1.40	0.04	.01	0.03	.18	1.30
1.44	0.04	.01	0.03	.18	1.30
1.48	0.04	.01	0.03		1.30
1.52	0.04	.01	0.03	.18	1.30
					1.30
					1.30
1.63	0.03	.01	0.02	.12	0.86
	Rainfall (Inches) 0.45 0.61 0.73 0.82 0.90 0.98 1.04 1.10 1.16 1.21 1.27 1.31 1.36 1.40 1.44 1.48	Rainfall (Inches) Rainfall (Inches) 0.45 0.45 0.61 0.16 0.73 0.12 0.82 0.09 0.90 0.08 0.98 0.08 1.04 0.06 1.10 0.06 1.21 0.05 1.27 0.06 1.31 0.04 1.36 0.05 1.40 0.04 1.48 0.04 1.52 0.04 1.56 0.04 1.60 0.04	Rainfall (Inches) Rainfall (Inches) Loss (Inches) 0.45 (Inches) 0.45 (Inches) 0.2* 0.61 (0.16 (0.2*) 0.02* 0.02* 0.82 (0.09 (0.08 (0.02*) 0.08 (0.02*) 0.98 (0.08 (0.02*) 0.06 (0.02*) 1.10 (0.06 (0.02*) 0.05 (0.02*) 1.21 (0.05 (0.02*) 0.02* 1.31 (0.04 (0.01*) 0.02* 1.36 (0.05 (0.02*) 0.02* 1.40 (0.04 (0.01*) 0.01 1.48 (0.04 (0.01*) 0.01 1.52 (0.04 (0.01*) 0.04 (0.01*) 1.56 (0.04 (0.01*) 0.04 (0.01*)	Rainfall (Inches) Rainfall (Inches) Loss (Inches) Rainfall (Inches) 0.45 0.45 0.2* 0.43 0.61 0.16 02* 0.14 0.73 0.12 02* 0.10 0.82 0.09 .02* 0.07 0.90 0.08 .02* 0.06 0.98 0.08 .02* 0.06 1.04 0.06 .02* 0.04 1.10 0.06 .02* 0.04 1.16 0.06 .02* 0.04 1.21 0.05 .02* 0.04 1.27 0.06 .02* 0.04 1.31 0.04 .01 0.03 1.40 0.04 .01 0.03 1.44 0.04 .01 0.03 1.48 0.04 .01 0.03 1.52 0.04 .01 0.03 1.56 0.04 .01 0.03 1.60 0.04 .01	Rainfall (Inches) Rainfall (Inches) Loss (Inches) Rainfall (Inch/Hr.) 0.45 0.45 .02* 0.43 2.58 0.61 0.16 .02* 0.14 .84 0.73 0.12 .02* 0.07 .42 0.90 .02* 0.06 .36 0.98 0.08 .02* 0.06 .36 0.98 0.08 .02* 0.04 .24 1.10 0.06 .02* 0.04 .24 1.16 0.06 .02* 0.04 .24 1.21 0.05 .02* 0.04 .24 1.21 0.05 .02* 0.03 .18 1.27 0.06 .02* 0.04 .24 1.31 0.04 .01 0.03 .18 1.40 0.04 .01 0.03 .18 1.44 0.04 .01 0.03 .18 1.48 0.04 .01 0.03 .18 1.52 0.04 .01 0.03 .18 1.56 0.04

^{*}Unit low loss exceeds unit adjusted loss
Discharge to 24 hours is calculated by the above method



SECTION K

WATERSHED MODELING GUIDELINES

K.I. INTRODUCTION

The previous sections provide the several elements used in developing a link-node watershed model for hydrologic planning purposes. In this section, guidelines are presented for development of complex hydrologic models for the analysis of the design storm condition. The combination of the several submodels described in Sections E-J provides the hydrologist with the modeling capability to analyze complex watershed conditions including variations in runoff production caused by flood control measures and alternative watershed development plans. It may be required that the difference in runoff production between existing and the ultimate development conditions be mitigated. For example, in large watersheds, the location of greenbelt channels or detention basins can significantly effect the total watershed peak flowrate estimate. Similarly, the planned location of high density development may mitigate the effects of watershed urbanization.

K.2. SINGLE AREA RUNOFF HYDROGRAPH DEVELOPMENT

In many cases, watershed studies involve a free flowing drainage system where storm runoff is collected by major storm drains or street systems and is carried from the watershed by means of a major flood control channel. These watersheds typically have minor storage or detention effects due to detention basins, channel constrictions, or channel capacity (i.e., overbank flow) problems. Additionally, these watersheds have a time of concentration which approximately equals the watershed critical duration and are comparable to the watersheds from which the S-graphs were derived.

Generally, a single basin unit hydrograph study such as illustrated in the example problem of Section E will be appropriate for the development of a design storm runoff hydrograph and peak flow rate (see Sections E and J).

K.3. COMPLEX WATERSHED RUNOFF HYDROGRAPH DEVELOPMENT

For complex watershed modeling conditions, the watershed is divided into subareas which are "linked" together by routing processes. Such watersheds are characterized by significant detention or storage effects and large areas of different development or soil loss conditions.

The procedures to be used for the various routing processes are given in the preceding sections. Subarea unit hydrograph and subsequent runoff hydrograph development follows directly from Section E.

- ì. Watershed Division into Subareas - All watershed modeling results differ based on the number and selection of subareas linked together to represent the total watershed. A guideline for the watershed division is to limit subareas such that the largest subarea is no greater than four times the area of the smallest subarea. Generally, subareas are defined which are tributary to detention basins or major channels whose storage routing effects are considered significant. Additionally, subareas should be determined such that the corresponding lag values are between 20 minutes and 2.5 hours; preferably, between 25 minutes and 1.5 hours (the range of lag values used in the calibration effort). Arbitrary subdivision of the watershed into subareas should generally be avoided. It must be remembered that an increase in the watershed subdivision does not necessarily increase the modeling "accuracy" but rather transfers the model's reliability from the calibrated unit hydrograph and lag relationships to the unknown reliability of the several flow routing submodels used to link together the several subareas.
- ii. <u>Subarea Design Storm Analysis</u> Each subarea is subject to the design storm condition. Therefore, all flood control facilities shall be analyzed based on the design storm impacting each subarea independently (see Section E).

iii. Depth-area Adjustment - As the watershed area increases, depth-area adjustment is needed based upon the entire tributary area. For example, should a point of concentration have three tributary subareas with a combined area of 6 square miles, then each of the subareas must be reanalyzed for the design storm condition with the depth-area factors based upon the total area of 6 square miles. All routing procedures are also reevaluated based upon the new subarea runoff hydrographs. In this fashion, each point of concentration has the appropriate depth-area adjustment applied to the design storm.

K.4. USE OF WATERSHED MODEL COMPUTER PROGRAMS

Several single event unit hydrograph computer models are currently available. For example, the unit hydrograph option of the HEC-1 and TR-20 programs have been used for both small and large watershed master planning. As discussed in Section E, unmodified use of these models are precluded. In the following, guidelines are presented which provide the parameter and design storm restrictions needed to conform the various available watershed models to the design storm conditions described in this manual:

- i. <u>Effective Rainfall Computation</u> All watershed loss rates are to conform to the specifications of Section C (i.e., watershed 24-hour storm runoff yields, maximum loss rates (Fm), and low loss fraction (\overline{Y})).
- ii. <u>Single Event Design Storm Pattern</u> The watershed model is to be based upon the design storm patterns shown in Section B. Depth-area adjustment and rainfall depths are to conform to the requirements of Section B.
- iii. Routing Processes Basin and channel routing modeling techniques are to be based upon the modified Pul's and convex methods described in the previous sections. (Full details of these techniques are contained in refs. 2, 3, 5.)

- iv. Complex Watershed Modeling The division of the watershed into subareas and the application of depth-area adjustment to tributary area must conform to the guidelines of this section of the manual.
- v. <u>Unit Hydrograph Development</u> The development of unit hydrographs must conform to the S-graphs and lag computation procedures described in Section E. Calculation of watershed time of concentration must conform to the rational method procedures of Section D.
- vi. <u>Preproject Meeting</u> All complex watershed modeling proposals are to be discussed with the Agency prior to study submittals for review. This preproject meeting will aid in familiarizing the project with the Agency, and also aid in checking whether the modeling approach conforms to the hydrology manual.

K.5. SINGLE AREA RUNOFF HYDROGRAPH COMPARISON CRITERIA

When a complex watershed model (e.g., a "link-node" schematic involving subareas linked by channel routing) is to be used, a single area runoff hydrograph model is also to be developed for comparison purposes. Should detention basins be planned, the complex model without the basins (i.e., "free-draining") is to be compared to a single subarea model.

Should the peak Q from the free-draining complex model be greater than the single area runoff hydrograph model, then the complex model peak Q is to be used as the design Q. The use of a higher Q for design purposes aids in accommodating for the increased uncertainty in the complex model.

Should the peak Q from the free-draining complex model be less than the single area runoff hydrograph model, then the design storm for the complex model is to be modified by uniformly increasing the rainfall used in the design storm until the peak Q values match between the two models.

SECTION L

PEAK FLOWRATE CURVES

L.I. INTRODUCTION

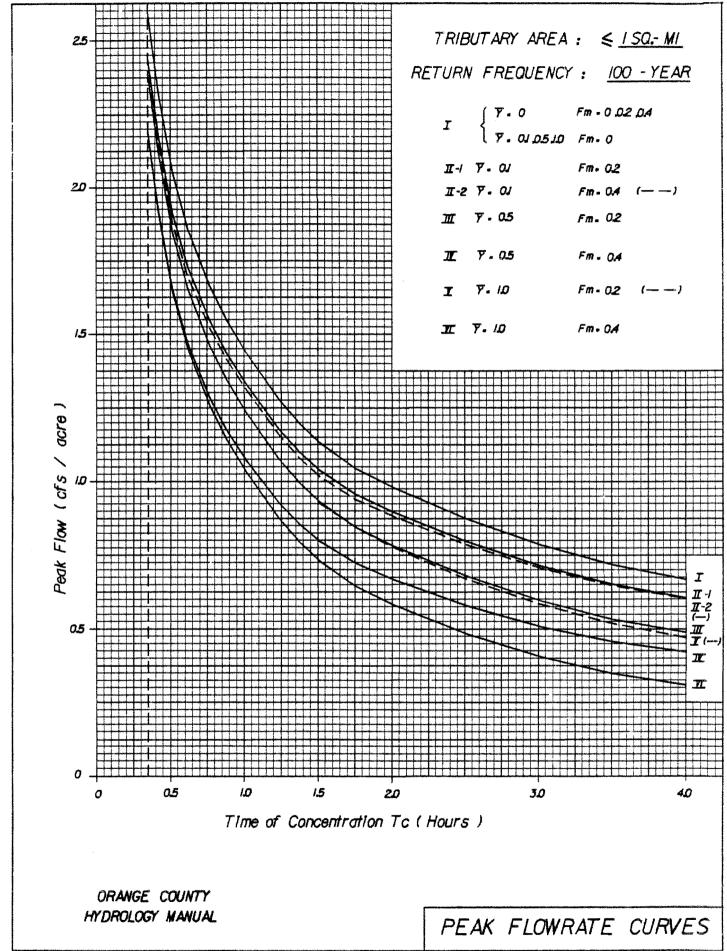
For a catchment where a single area unit hydrograph is appropriate to model the watershed response, the design storm peak flowrate can be readily determined as a function of watershed area, time of concentration (Tc), and the loss parameters of F_m and \overline{Y} .

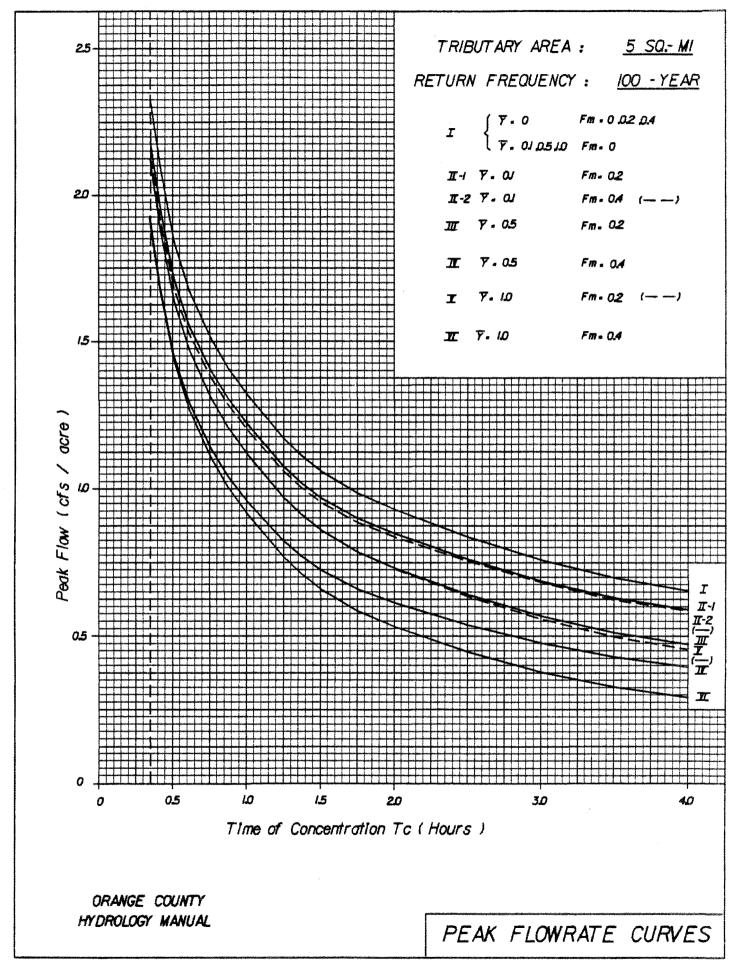
Plots are provided in this section which give cfs/acre for catchment area sizes of 1, 5, 10, 25, and 50 square miles, F_m values between 0.0 and 0.4 inches/hour, \overline{Y} values between 0.0 and 1.0, and Tc values between 20 minutes and 4 hours. Plots are provided for the 2-, 5-, 10-, 25-, 50-, and 100-year design storm conditions for the nonmountainous areas of Orange County where the Valley:Developed S-graph applies.

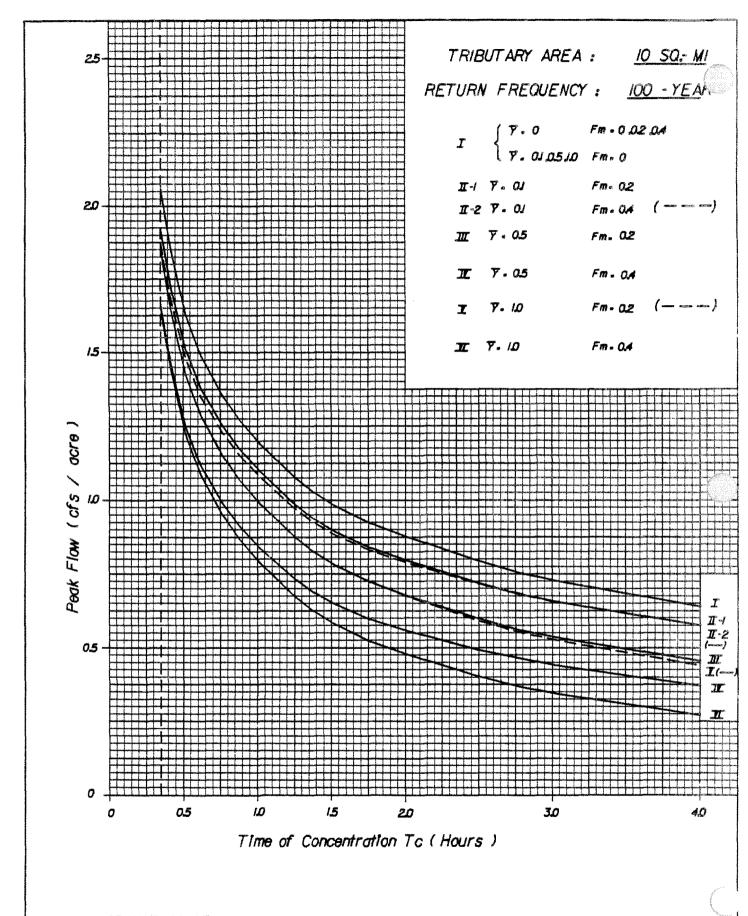
The peak flowrate curves are used by simply averaging the cfs/acre values between the appropriate watershed area plots of the assumed loss rates.

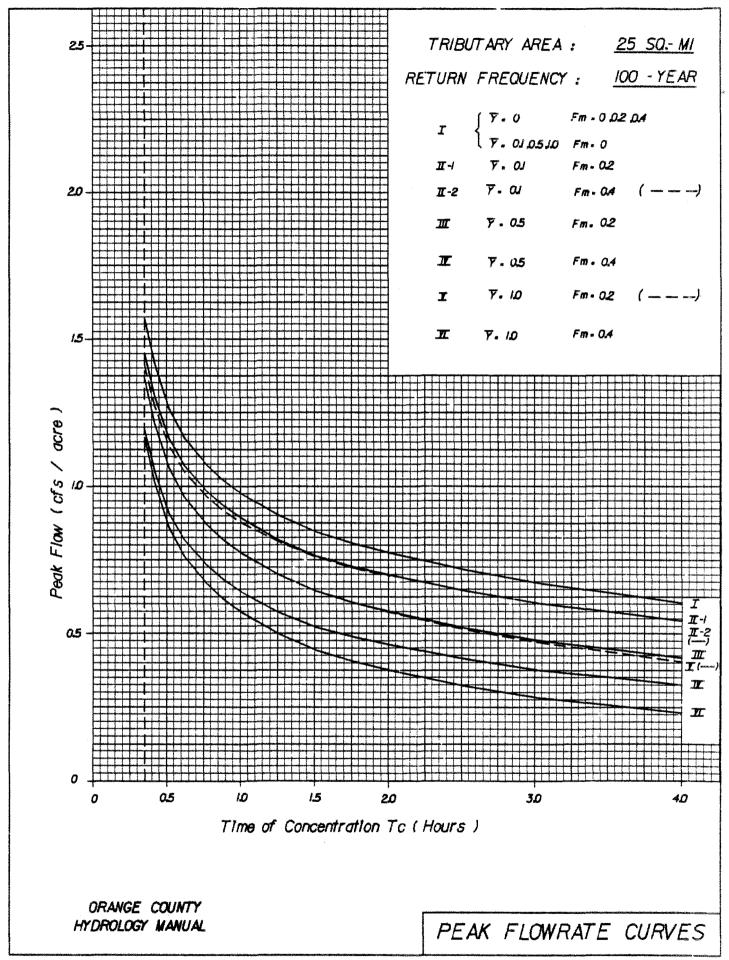
L.2. TIME OF CONCENTRATION ESTIMATION

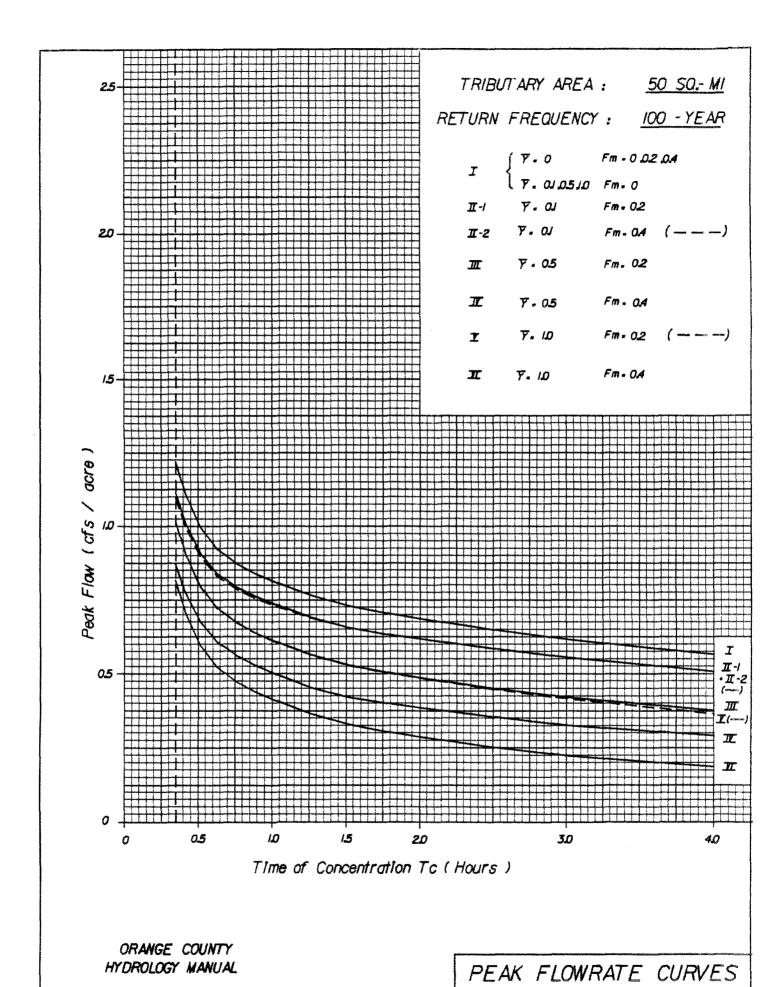
For estimating the time of concentration, Tc, for a catchment, the rational method (Section D) can be used for catchment areas less than I square mile. For larger areas, the peak flowrate curves are used to develop the intermediate Q estimates used in a rational method analysis. That is, rather than using a rational method estimate of CI to develop cfs/acre, the peak flowrate equations are used. Otherwise, the methods used for estimating subarea traveltimes are applied to the entire catchment drainage system just as used in the rational method of Section D.

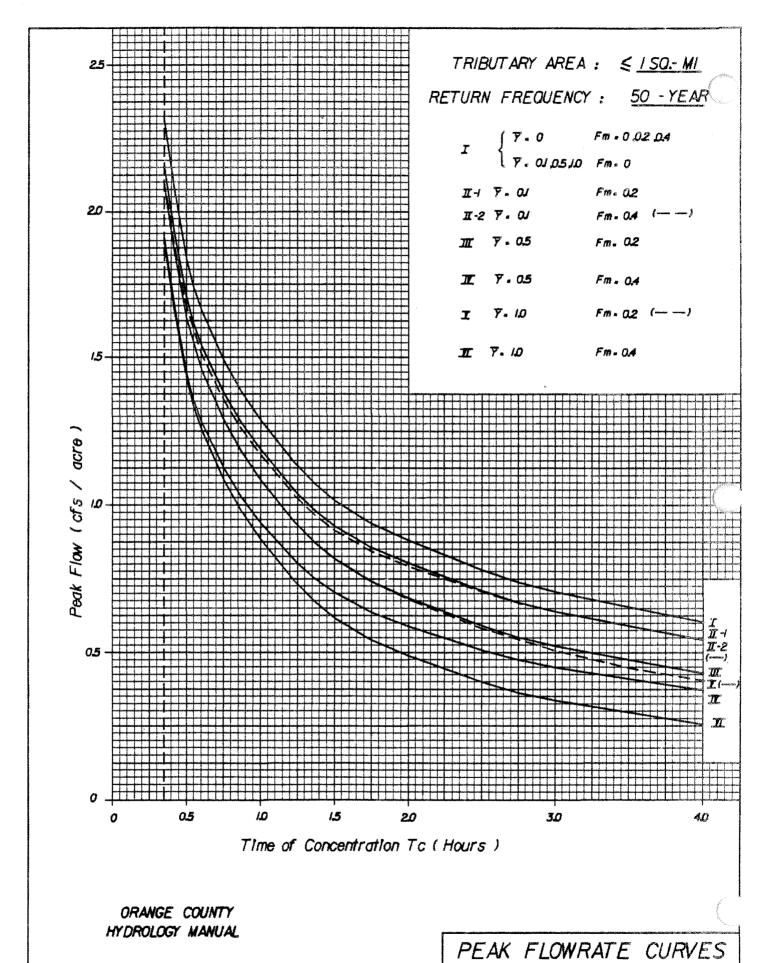


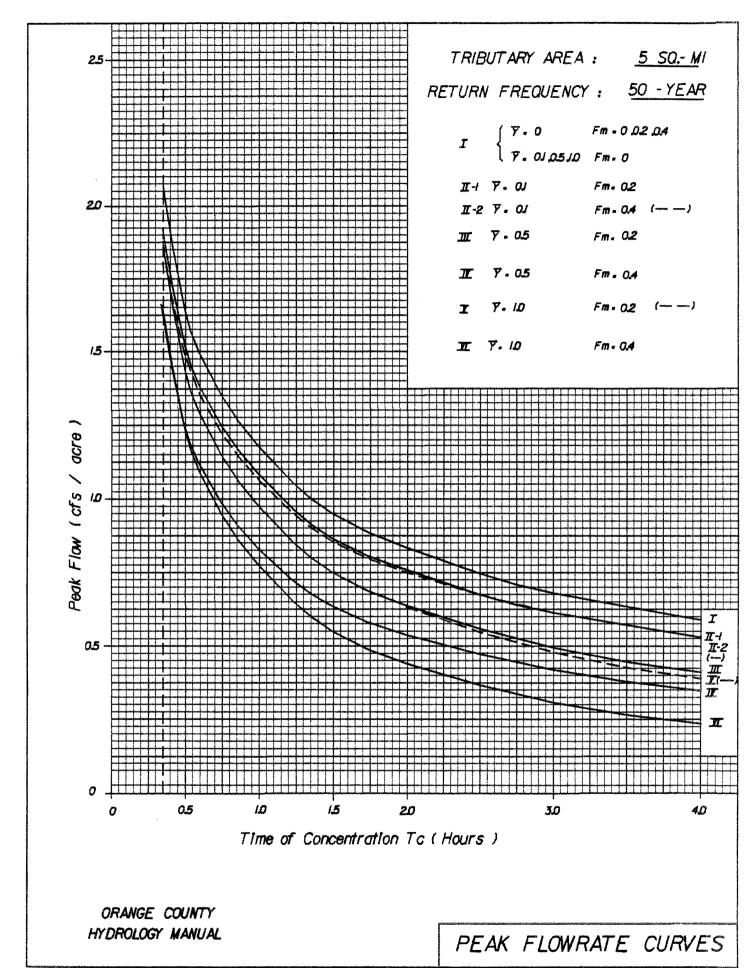


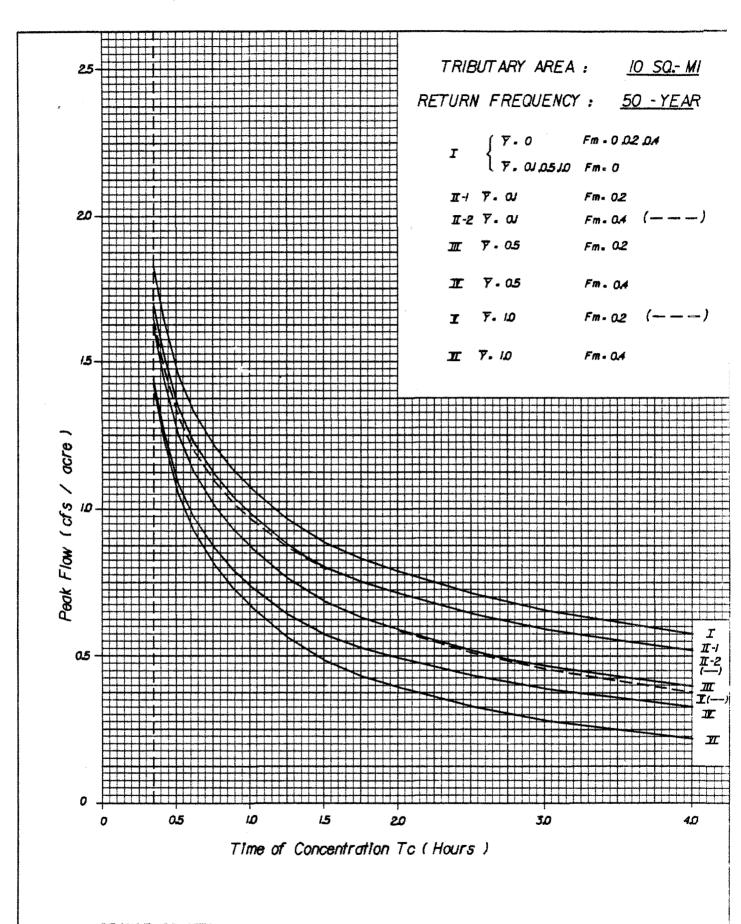


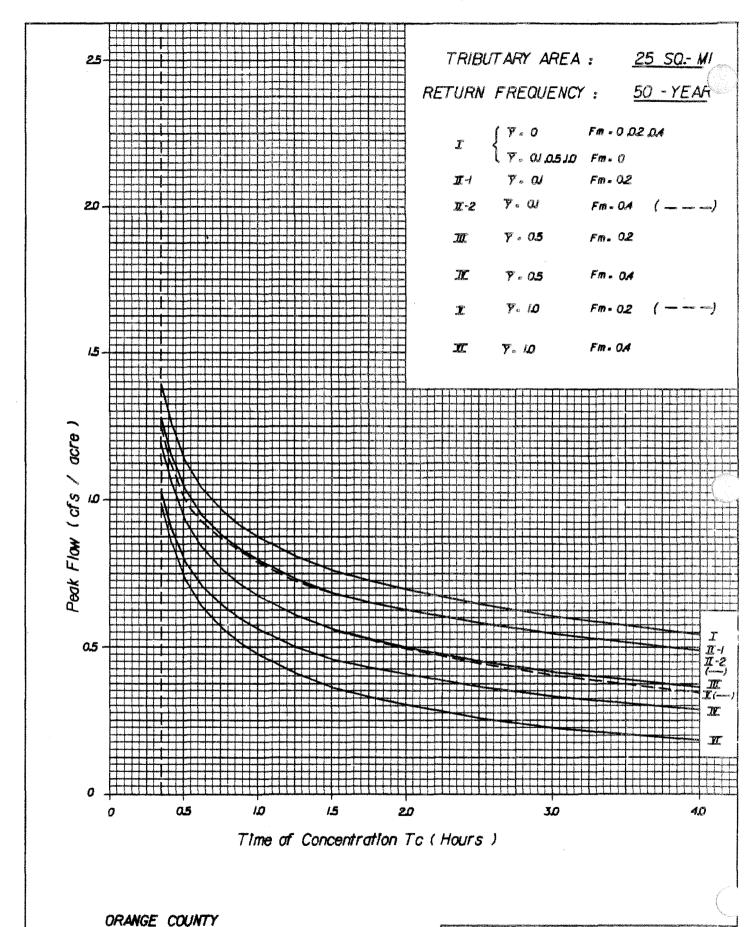




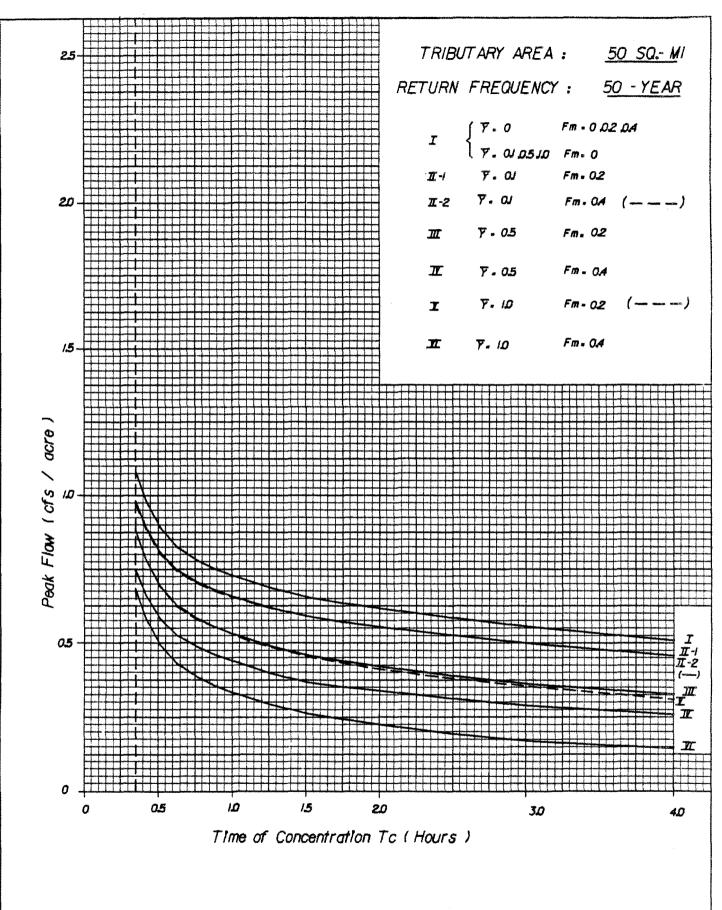


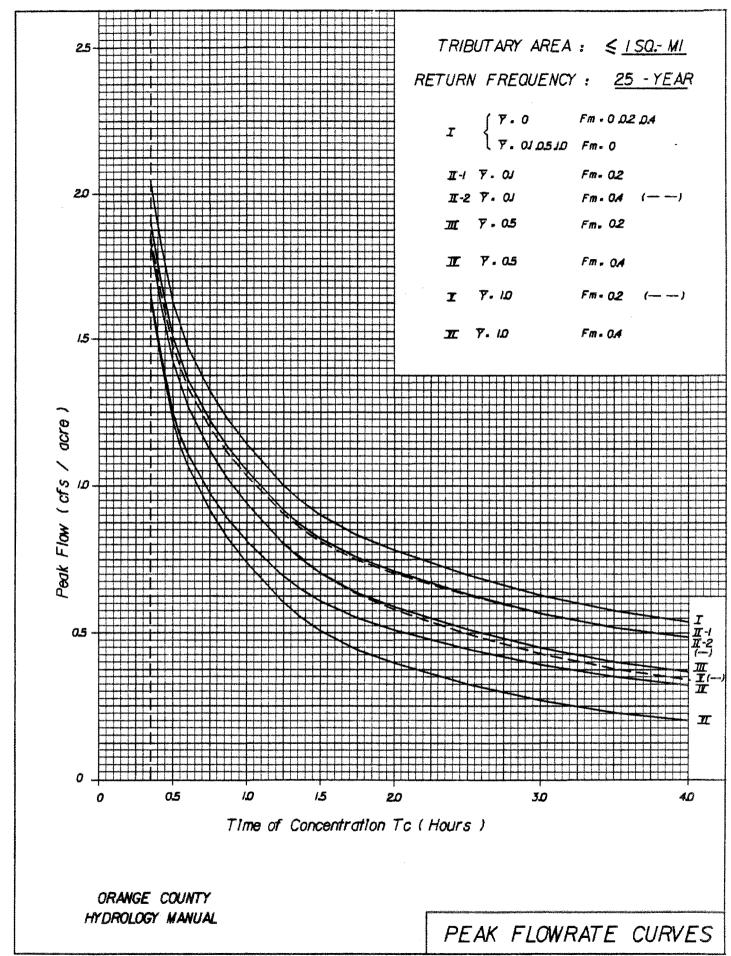


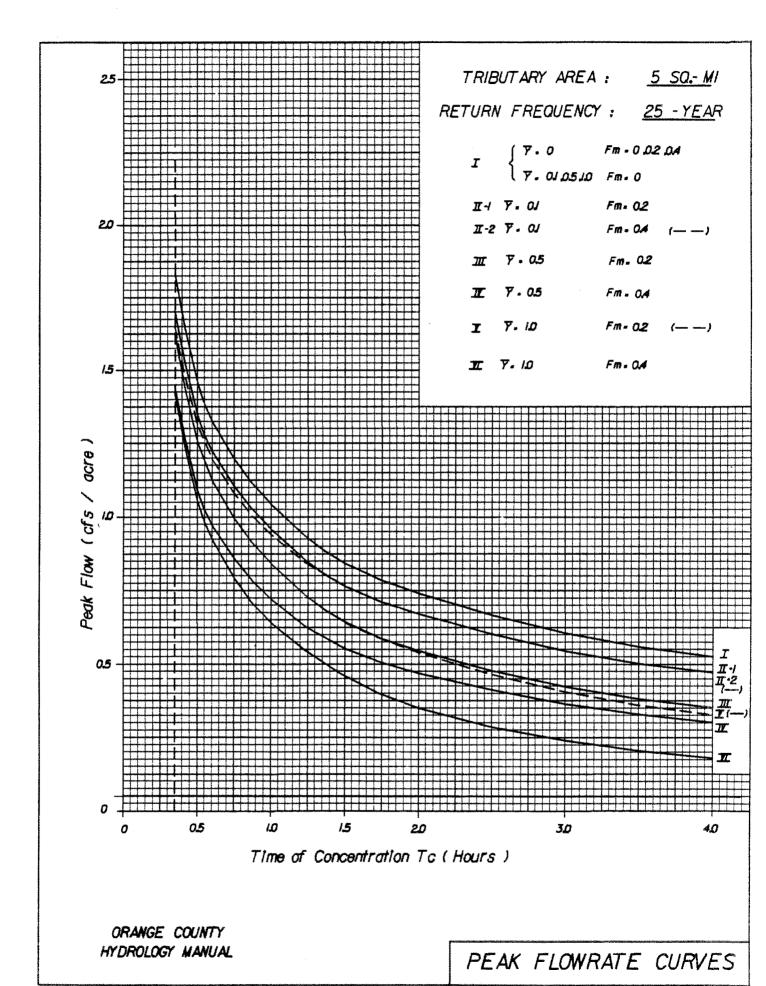


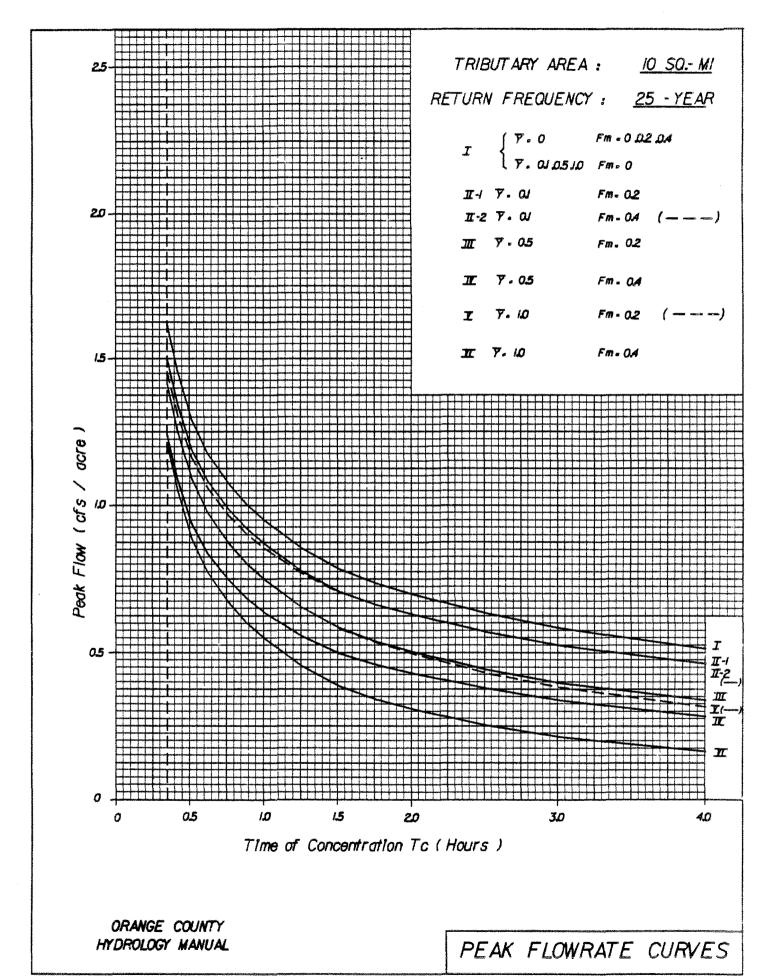


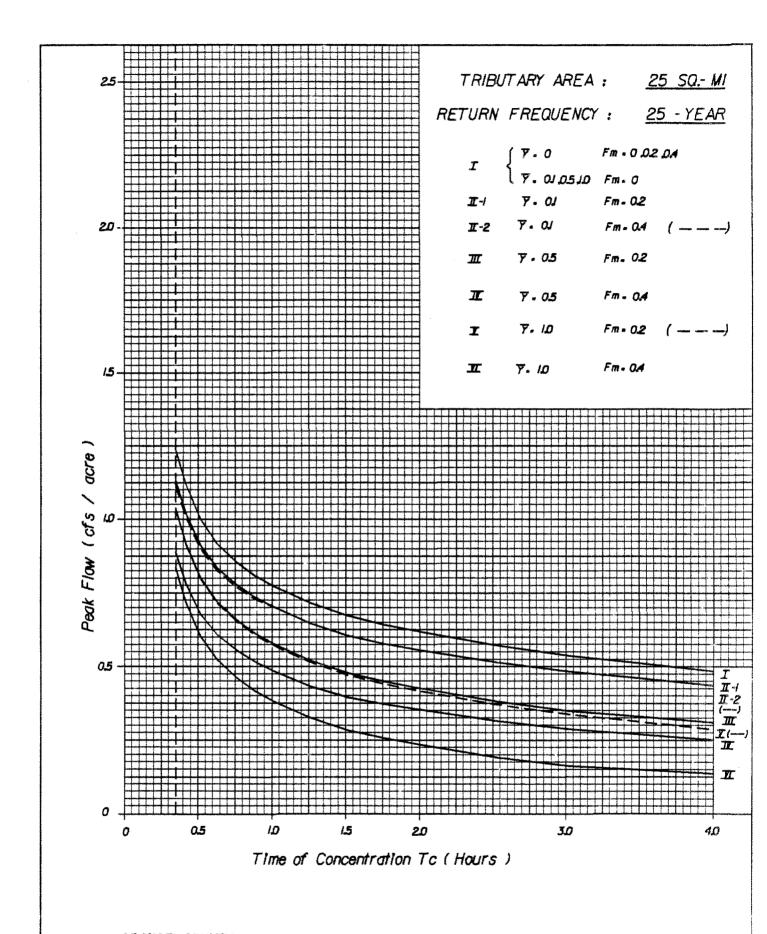
HYDROLOGY MANUAL

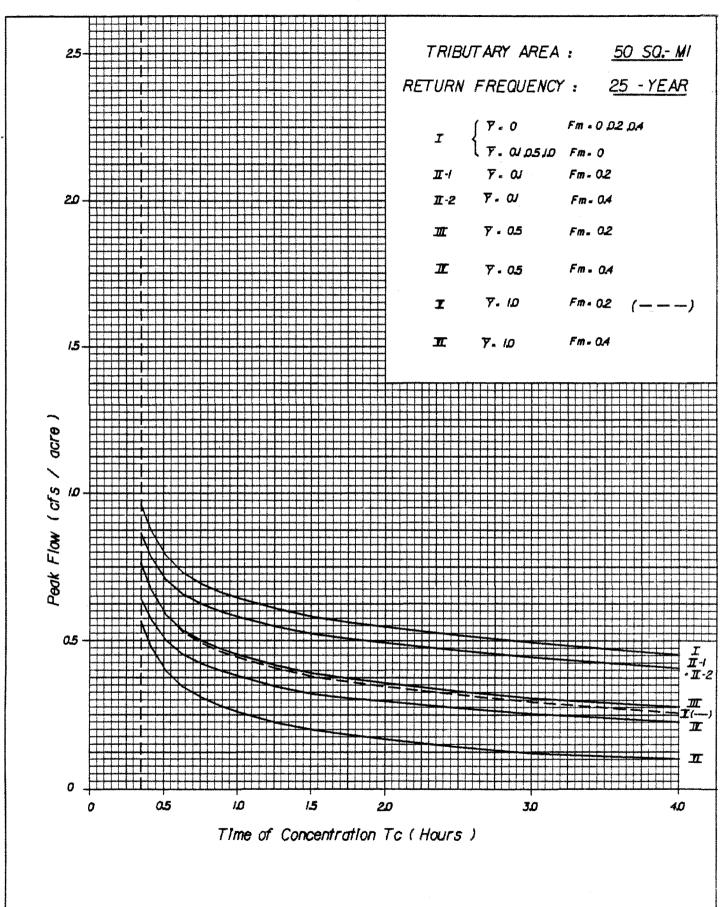


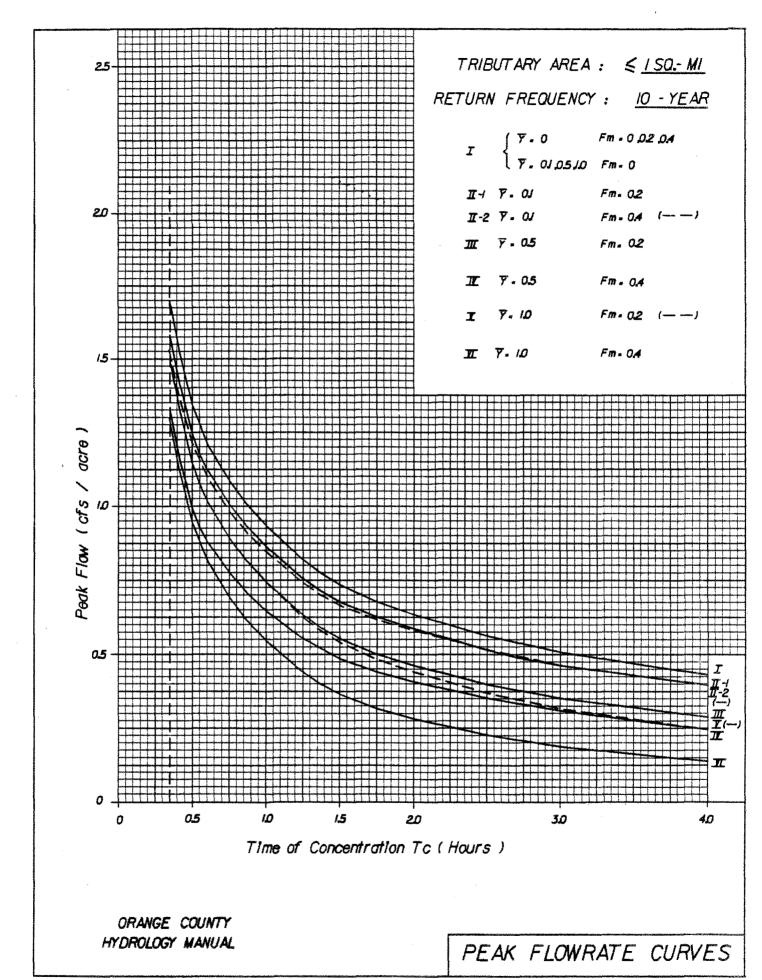


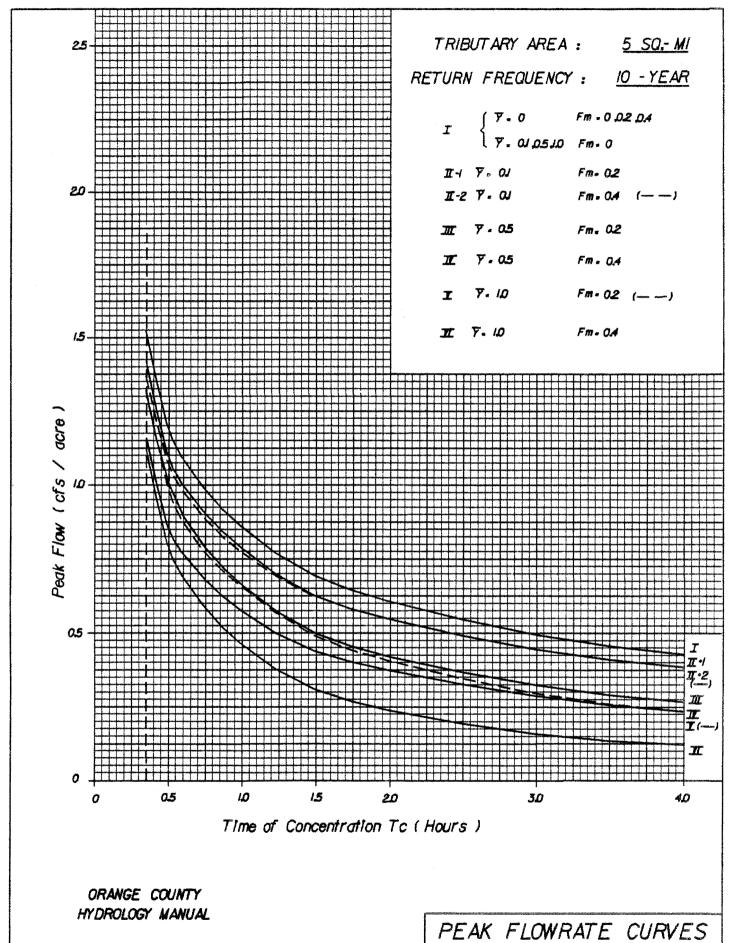


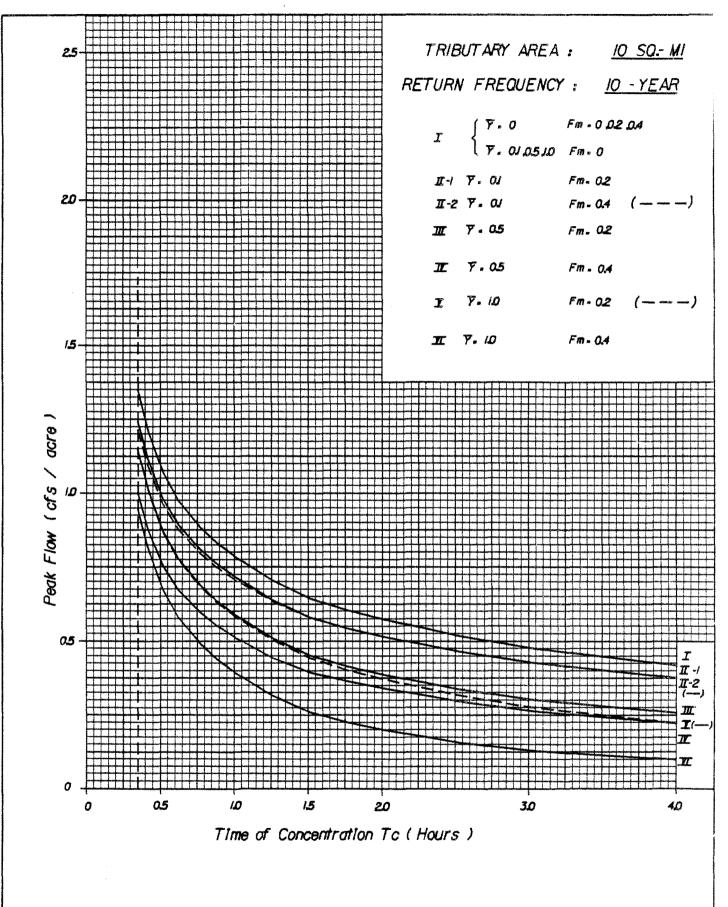


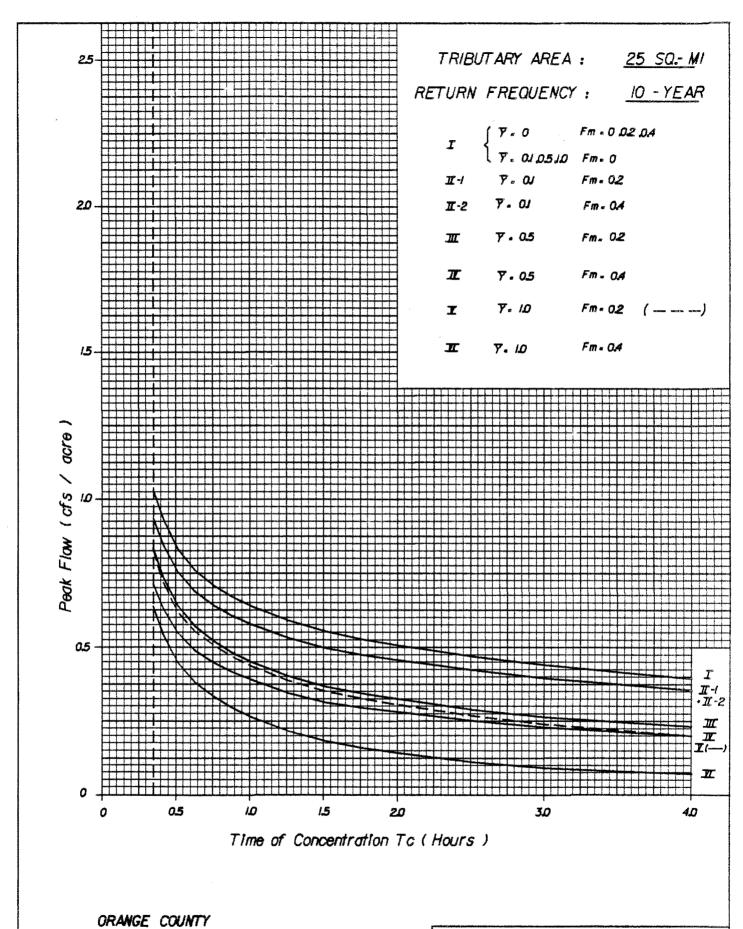




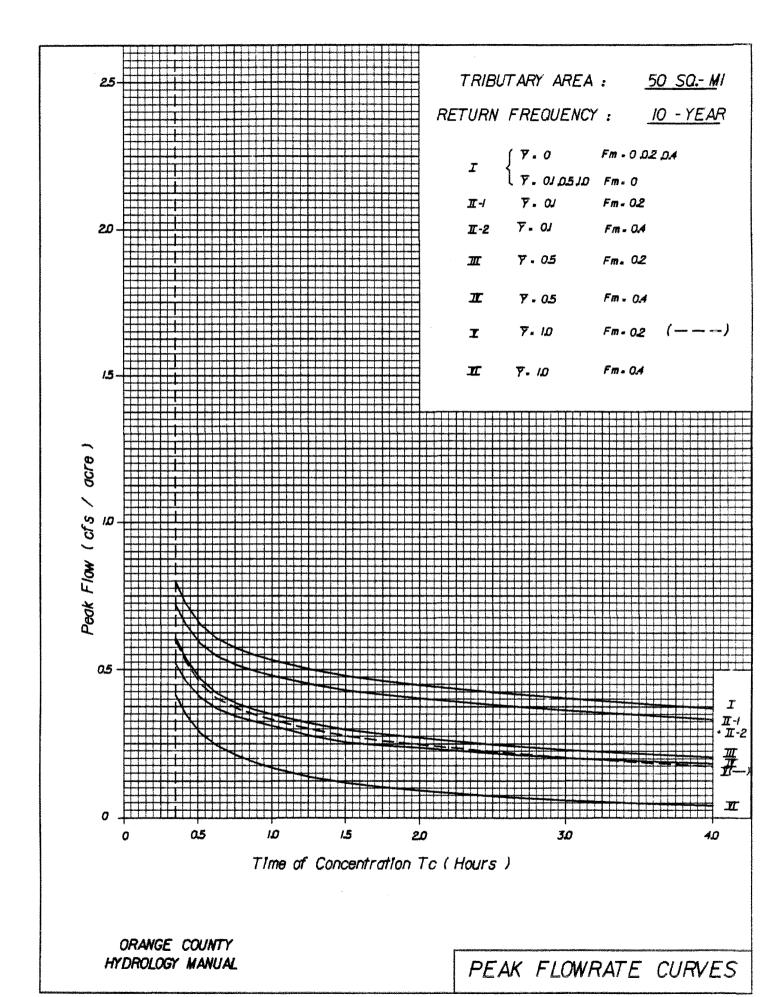


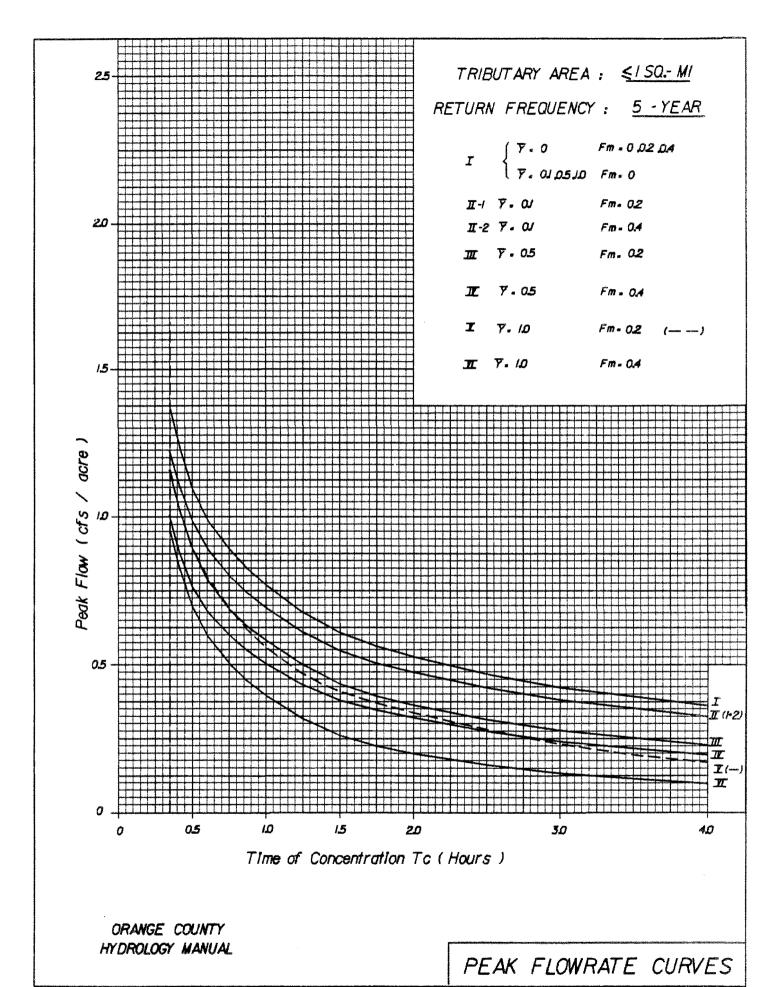


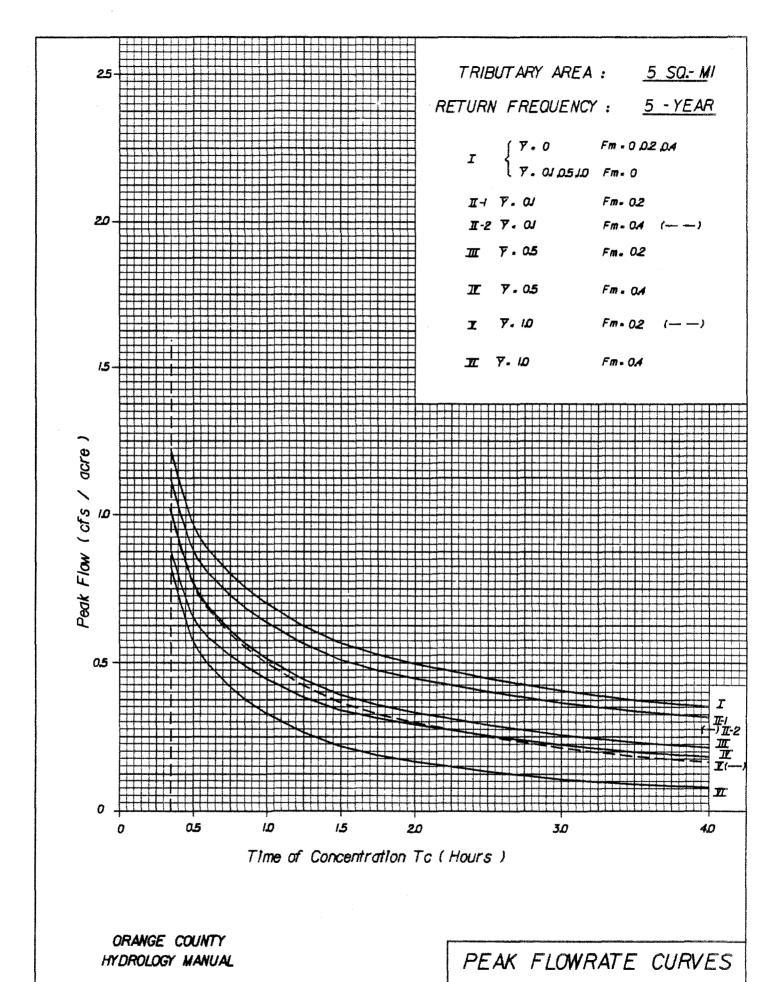


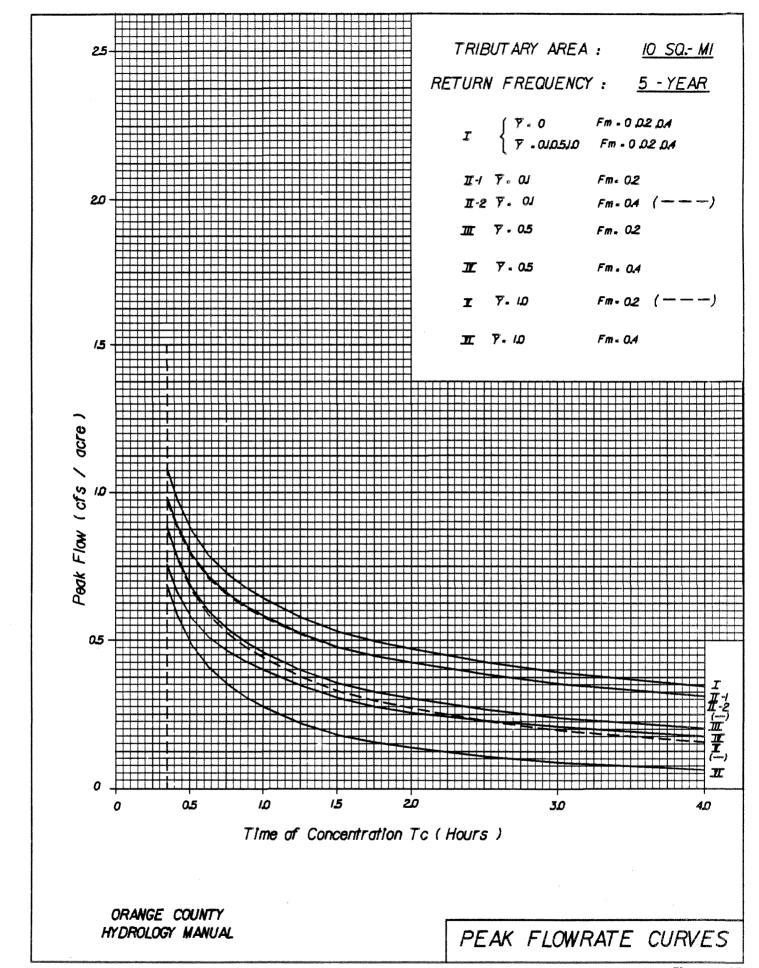


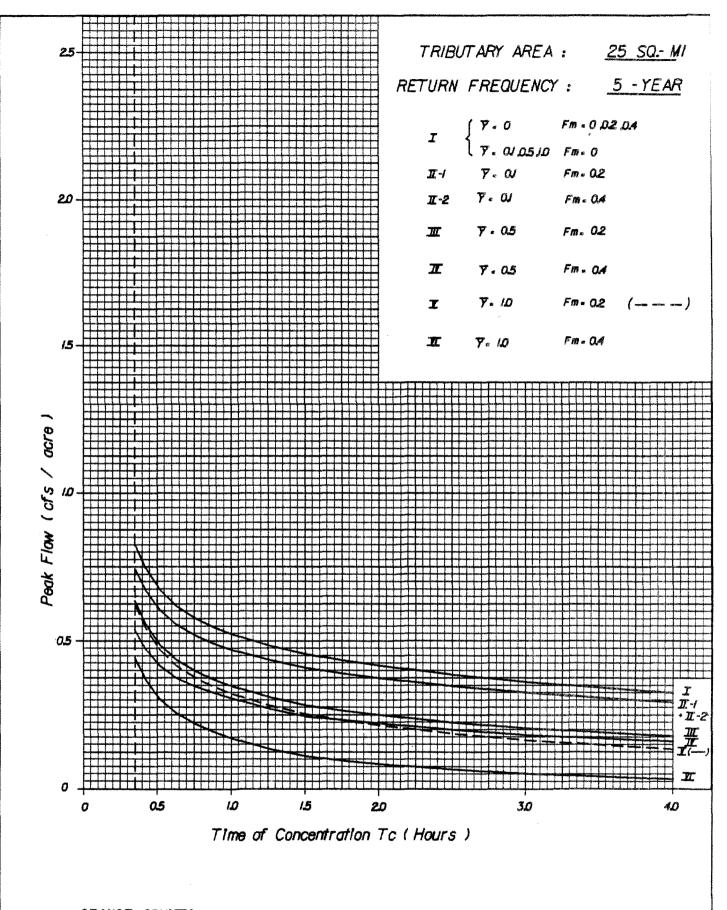
HYDROLOGY MANUAL PEAK FLOWRATE CURVES

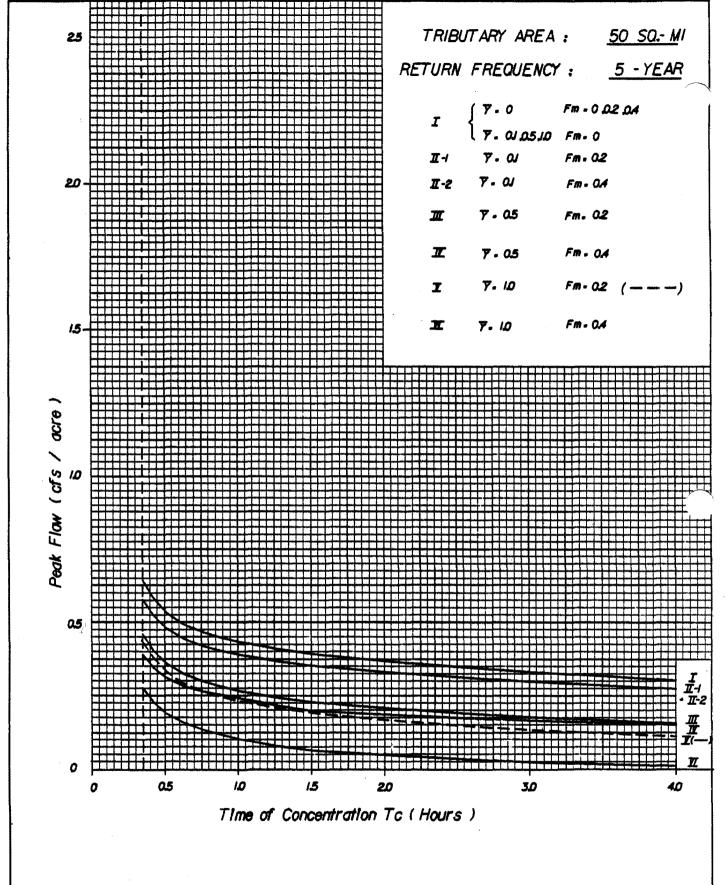


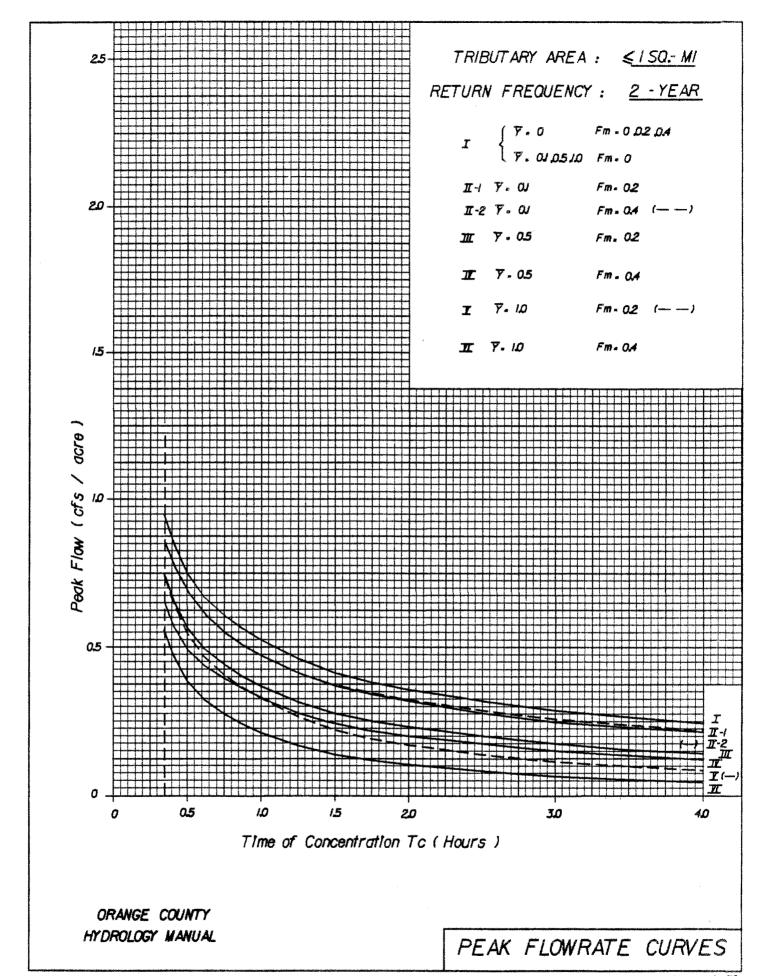


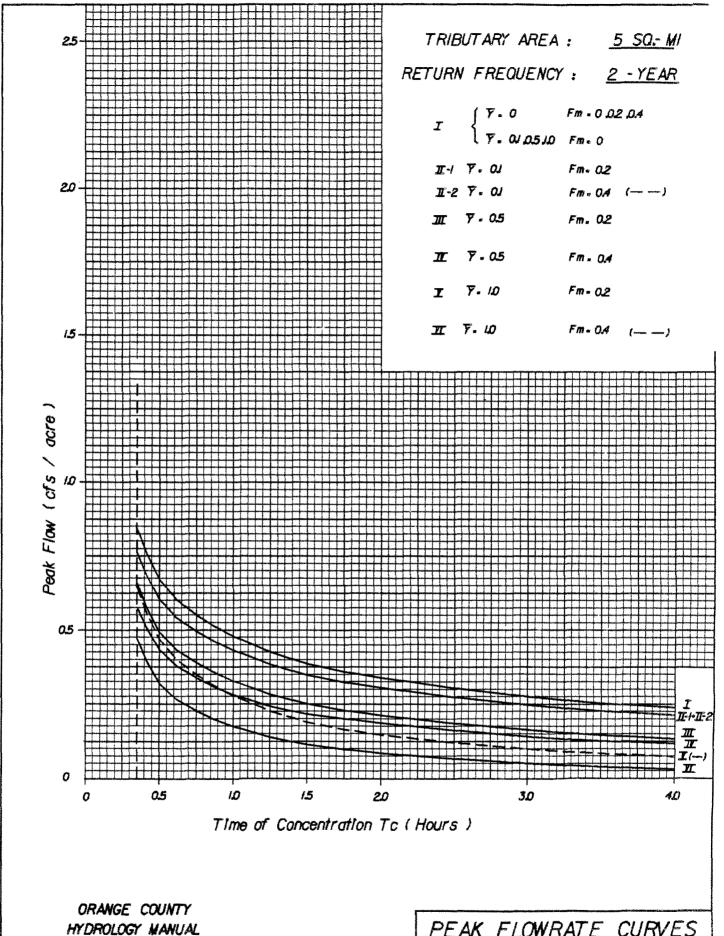


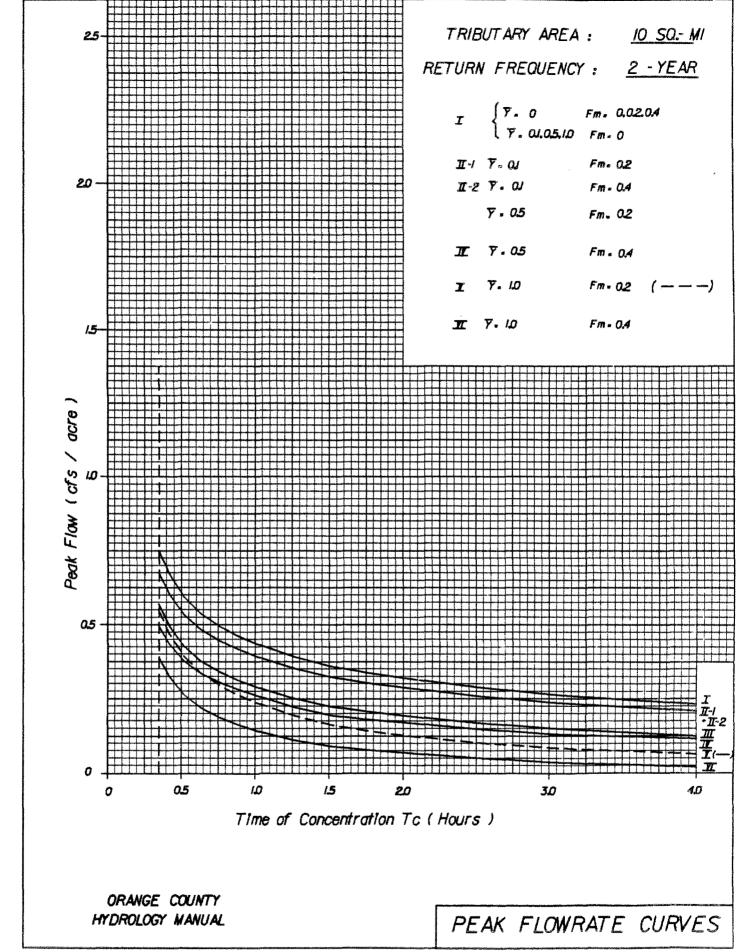


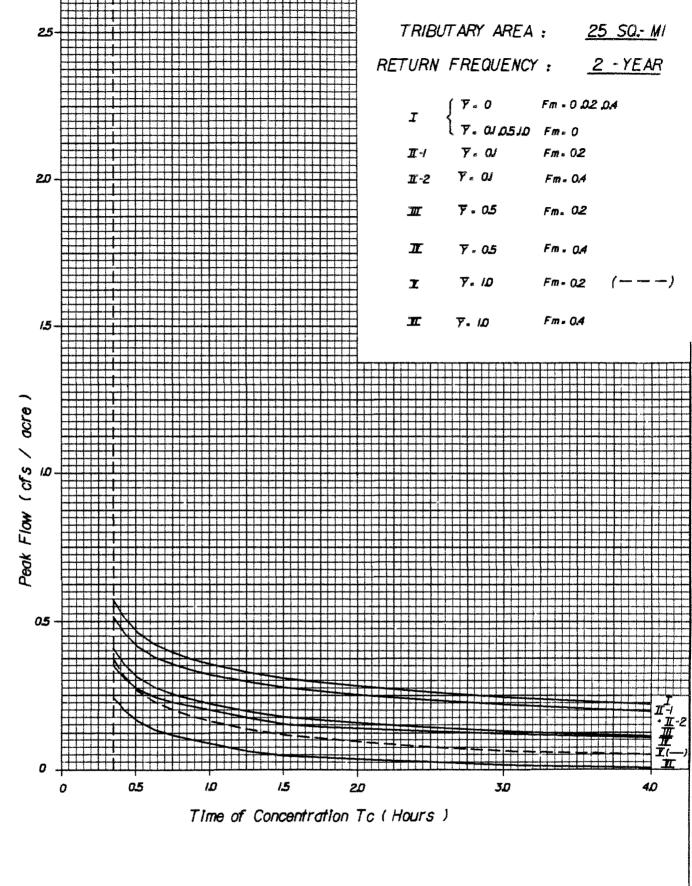






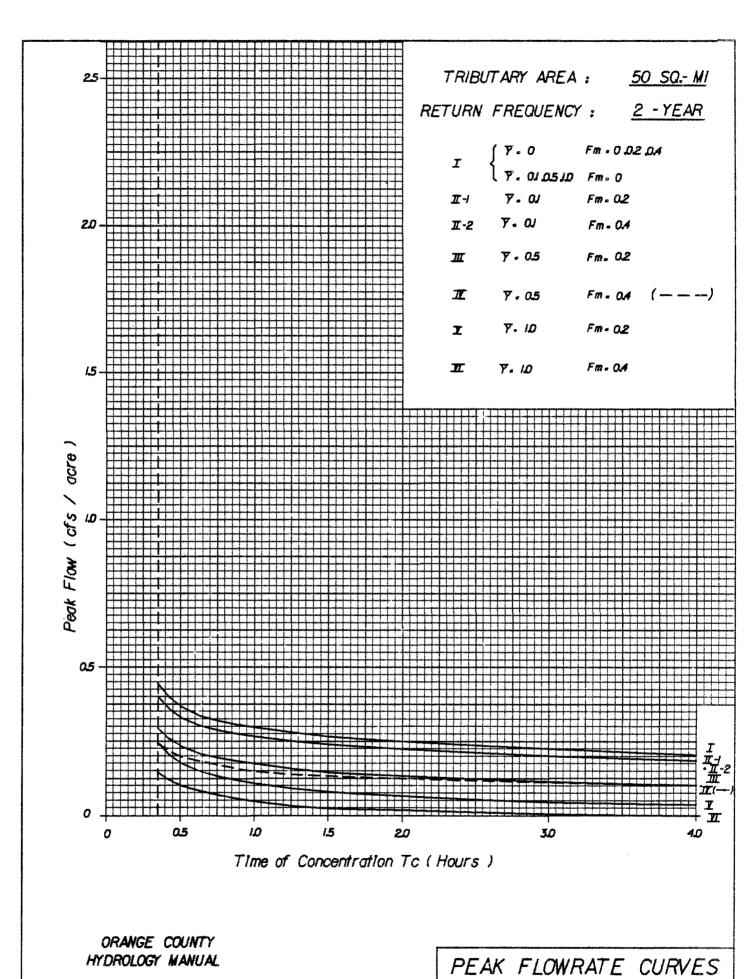






ORANGE COUNTY
HYDROLOGY MANUAL

PEAK FLOWRATE CURVES



APPENDIX I

I.I. HYDROMETEOROLOGICAL CHARACTERISTICS

Precipitation in the County results from three distinct mechanisms. The most important is the convergence mechanism associated with general winter storms. These storms originate as low pressure cells in southern Alaska, arcing across the Pacific Ocean and picking up moisture as they move south and east. On occasion, these storm tracks move far enough south so that precipitation is widespread across southern California. The second major precipitation mechanism occurs through orographic lifting, and is also associated with general winter storms. As storm tracks move into the southern California coastal areas, winds usually travel easterly. Mountain masses deflect moisture laden air masses upward, increasing condensation and precipitation. The Santa Ana Mountains present a natural barrier to such air masses and increase precipitation amounts by orographic lifting in the eastern most portion of Orange County.

The third class of mechanisms causing intense precipitation are the convective mechanisms. Such mechanisms produce thunderstorms which usually produce very intense rainfall and hail for relatively short durations. Such storms are usually of small areal extent. One of the most intense convective rainfall events of record in southern California occurred at Campo, California, near the Mexican border, producing over 11 inches of rainfall in about 80 minutes.

Occasionally, unstable tropical air masses invade southern California and produce rainfall. These air masses are generally associated with convergence mechanisms; however, because of instability, pockets of convective activity may occur and produce intense thunderstorms (e.g., Arnold Court, NWS WR-158, Oct. 1980, "Tropical Cyclone Effects on Southern California.")

The major floods in Orange County have been primarily the result of orographic storm precipitation. However, it is known that convergence precipitation can contribute a significant portion of the total rainfall in a predominantly orographic storm. The cyclonic circulation inherent in all large orographic storms, for example, involves horizontal convergence and assures widespread convergence precipitation in nearby non-orographic areas. Convergence bursts are observed during periods of heavy orographic rain. Thus, the occurrence of large amounts of convergence and orographic precipitation in the same storm is an established fact. These general observations are supplemented by the severe coastal storms of 1974 and 1983, both of which produced more rainfall near the coast than in the eastern mountains.

Major storms in Orange County occur in the cooler months from October to April. Storms typically originate with cyclonic disturbances along the polar front in the vicinity of the Aleutian Islands. As a storm center moves southward, meteorological conditions usually force the storm inland before the southern California latitude is reached, precipitating the greatest quantity of the storm's moisture on the northern Pacific areas. The usual result is relatively gentle rainfall in the southern California areas continuing sometimes for many days. Occasionally, with the right combination of conditions, storm producing air masses move directly southward over the Pacific Ocean picking up warmth and moisture at low levels and remaining cold and humid at higher levels. Such storms may sweep in on the southern California Coast. As moisture laden air encounters the Santa Ana, San Bernardino, San Gabriel and San Jacinto mountains, it is deflected upward where cooling and pressure reduction induce precipitation. A typical storm of this type was that of February 27 to March 4, 1938 which resulted in one of the most disastrous floods of record in southern California.

The approach direction of the storms which reach Orange County may vary from northwest through west to southwest. For example, satellite tracking records indicate that storm cells may approach Orange County from the southwest, originating from tropical hurricanes located westerly of central Mexico.

It is common for successive storms of varying duration and intensities to compound their effects, with the heavy rainfall of the second or third storm creating the more severe flood conditions. It is known that the rainfall once lasted for approximately thirty days with relatively few breaks, covering the period from December 24, 1861 through January 24, 1862. It is probable that this deluge included two or more individual storms.

I.2. FLOOD HISTORY

The history of floods in Southern California pivots on the year 1825. Prior to 1825 the surviving documents, principally from the Spanish missions and a few personal diaries, are very few and quantified data and maps of inundation are entirely absent.

The following chronology is abstracted from many sources and is focused on the great floods which have inundated southern California (excluding descriptions of storms such as Campo (1891), Indio (1939), San Bernardino (1983) and others that struck desert areas):

- 1825 The Los Angeles River changed its outlet from Santa Monica Bay to its present location in San Pedro Bay. The Santa Ana River changed its outlet from Anaheim Bay (Seal Beach) to Newport Bay.
- The greatest flood in the history of California. Water flowed four feet deep through central Anaheim as the Santa Ana River sought to find its historic outlet in Seal Beach. Documented by paleohydrologic methods in 1967 as delivering 315,000 cfs near the present Route 60 bridge, a discharge three times larger than any subsequently measured flow at any point on the Santa Ana River. The recently acquired knowledge about the magnitude of this event has influenced the design of the proposed Santa Ana River improvements by the Corps of Engineers.

- 1891 Thirty inches of rain measured at Big Bear in 36 hours.

 Overbank flows produced great damage in San Bernardino County.
- Thirty inches of rain over 15 days measured in San Diego where Otay Dam failed disastrously, Sweetwater Dam was severely damaged and all road and rail traffic into the city of San Diego was blocked by damaged bridges for a month. Supplies were delivered by boat and barge until the bridges were restored. Detailed maps show that western Orange County was inundated by the Santa Ana River (75,000 cfs) again seeking its historic outlet in Seal Beach. Santiago Creek overflow along Prospect Avenue reached Newport Bay and created a large lake near the present blimp hangers at the Marine Corps Air Station.
- 1938 The largest flood in Southern California since 1862. The Santa Ana River inundated western Orange County again in a pattern similar to 1916 but the higher flows (100,000 cfs) and denser development led to 45 fatalities.
- Two long duration, moderate intensity but high volume storms in January and February led to uncontrolled spillway flow at Santiago Dam and Villa Park Dam. The January storm was the most severe in Orange County since 1938 and the February storm was still larger. The sustained discharges over many weeks produced severe erosion damage to unlined flood control channels throughout the county. Water flowed over the Santa Ana Freeway in the Irvine area. The spillways at both dams on Santiago Creek were damaged. Two bridges failed and many were damaged.
- 1974 The first large scale high intensity storm to strike Orange County after the Orange County Flood Control District installed its network of automatic recording rain gauges. Three hour, 100-year rain depths covered approximately 100 square miles near the coast. Record breaking rainfall

did not extend inland past the Santa Ana Freeway contradicting the conventional prediction that rainfall from large storms would be greater in the mountainous inland areas than at the coast. Widescale local flooding occurred in coastal areas.

- 1978-1980 Both years had extremely high annual total rainfall (second and seventh greatest since 1909). The duration of the 1980 flows in the Santa Ana River combined with levees saturated by weeks of rainfall led to severe invert erosion (greater than 20 vertical feet at the Fifth Street bridge) and lining failures over the entire length of the channelized river in Orange County.
 - 1983 -At approximately 7:00 a.m. on March 1, 1983 a winter storm of record breaking intensity struck the westerly portions of Orange County. By 2:00 p.m., when the rainfall slackened, most of the short duration rainfall intensity records for the heavily urbanized central Orange County area had been broken. Arterial highway traffic was heavily congested by flooded intersections, local streets were overflowing, the Santa Ana Freeway was closed to all traffic for a period of 20 hours in Irvine, excessive storm runoff had overtopped the banks of numerous flood control channels and several leveed channels had been breached by overflowing storm water. Fortunately, the devastation was limited by the short duration (approximately 6 hours) of the storm and limited areal coverage (100 square miles) of the County. Even so, 1,100 homes were flooded with damages over \$160,000,000 including public property losses.

Recording rain gages maintained by the county showed record breaking rainfall intensities for durations between 15 minutes and 6 hours at several locations. Watershed areas tributary to most Orange County flood control facilities (other than the Santa Ana River) have times of

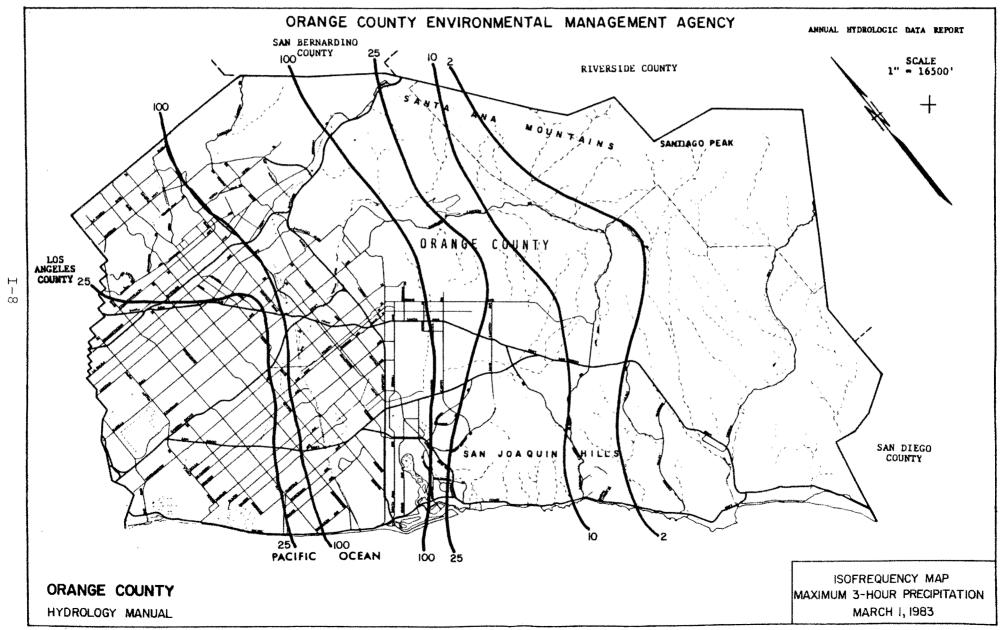
concentration ranging from 30 minutes to 3 hours for the water to drain from the uppermost watershed boundary to a point of discharge into a larger facility or the ocean. Therefore, the March 1st storm was a particularly severe test of these local facilities. In contrast, the much larger watershed of the Santa Ana River is most sensitive to heavy rainfall sustained over a period of several days. Accordingly, the Santa Ana River was not severely tested in this storm.

The recording rain gage for which the county has the longest record of short duration rainfall amounts has been in operation for 51 years in the city of Santa Ana. A shorter period of record is available at the Costa Mesa recording rain gage. Table I.1 illustrates the record breaking intensity of the March 1st rainfall by comparison with previous records.

TABLE I.I. MARCH 1, 1983 STORM RAINFALL

Duration (Min.)	Santa Ana		Costa Mesa	
	51-Year <u>Record</u>	March 1 Rain (Inch)	28-Year <u>Record</u>	March I Rain (Inch)
30 60 120 180 360	1.06 (1941) 1.45 (1941) 1.76 (1974) 2.07 (1974) 2.93 (1941)	1.12 1.72 2.25 2.65 4.00	1.11 (1978) 1.28 (1978) 1.58 (1978) 1.65 (1978) 1.86 (1979)	1.47 1.93 2.26 2.98 3.82

Figures I-1 and I-2 illustrate the area of most significant rainfall, which in turn, indicate the areas where flood channels were most severely affected. Flood channels which overflowed were largely those which were constructed of earthen levees. It is important to note that



the rain depths in Santa Ana and Costa Mesa for durations of 30 minutes through 6 hours are all approximately one hundred year values according to the State Department of Water Resources depth-duration frequency tables for Orange County. Figures I-1 and I-2 show that large areas were blanketed by one hundred year recurrence interval rain depths. In this regard the March 1 event is similar to the storm of December 4, 1974, in Orange County where comparably large areas were blanketed by 100-year rain depths (Fig. I-3) and rain depths were also greater near the coast than in the eastern mountains. Flooding resulting from the 1974 event was lessened by the mild antecedent moisture conditions. The 1974 event was the first severe storm of the season. The March 1, 1983, event followed five days of light to moderate rainfall. Such antecedent rainfall fills depression storage in the watershed and reduces soil infiltration to the saturated rate.

The March 1, 1983 storm is important in County of Orange Storm Water Management (SWM) policy due to the magnitude of rainfall intensities during the peak six hours being comparable with the design storm pattern used in this hydrology manual, and also due to the eight days of antecedent rainfall.

From the above list it is evident that seven storms in the last 161 years (every 23 years on the average) have produced widespread flooding in Orange County and only two of the storms are adequately represented in the rainfall data used in this manual (1974 and 1983).

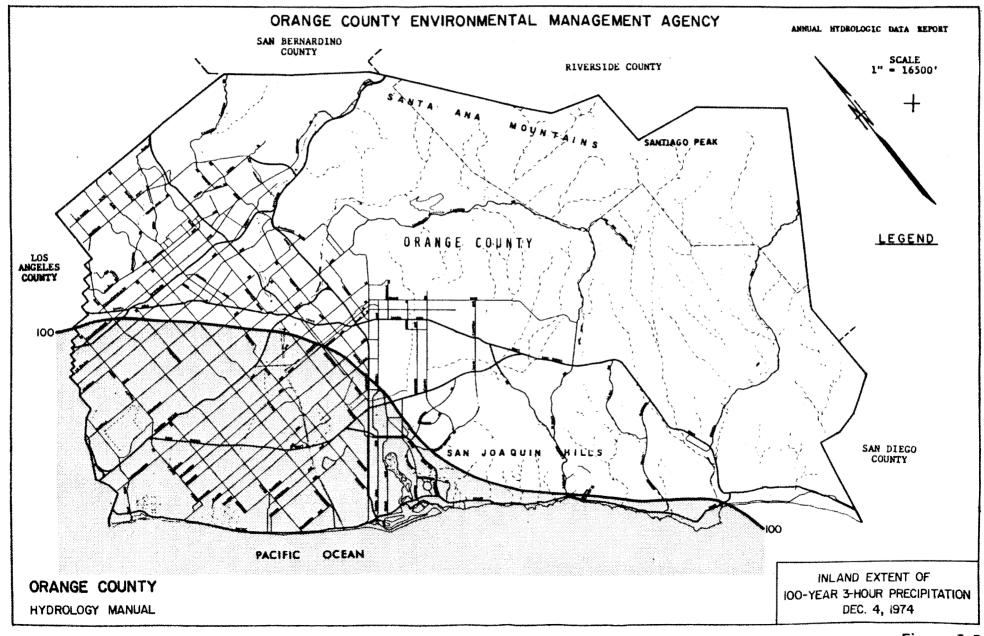


Figure I-3

APPENDIX II

II.I. MEASUREMENT AND SYNTHESIS OF PRECIPITATION DATA

Of interest for hydrologic studies is the maximum intensities of precipitation possible throughout a watershed. Given a long history of such maximum rainfall intensities for various durations of time, a reasonable statistical interpretation can be made of the data to determine estimates of maximum rainfall intensities or depths as a function of storm duration and of return frequency. The Orange County Flood Control District maintains and operates both automatic recording and standard (manual) rain-gages throughout the county and summarizes the data in its annual Hydrologic Data Report. Other sources of precipitation data include the U. S. Weather Bureau, U. S. Army Corps of Engineers, U. S. Geological Survey and other private and governmental cooperative weather observers.

For each automatic recording rainfall gage, the precipitation records are analyzed to determine the annual maximum rainfall depth for several durations of interest (e.g., 5-minutes, 10-minutes, 15-minutes, etc.). This data can then be arranged in an increasing order of magnitude for each storm duration for the history of the rain-gage, and plotted on normal probability paper. From this accumulation of rainfall depth-duration data, various statistical models can be applied to assign a return frequency (or period) to the known data values and to estimate maximum rainfall depth-duration values for typically unmeasured higher return frequencies (e.g., the 100-year return frequency). The resulting data for each rain gage is generally termed "point precipitation" values to distinguish them from average values for large areas.

Because storm events seldom locate their peak intensities over rain-gages, and because the rain-gage network is widely distributed (allowing small intense rainfall events to miss the gage network), and because of mechanical defects of the gage devices and wind effects, the rainfall data can generally be assumed to underestimate the true maximum point rainfall intensities.

II.2. SYNTHETIC 24-HOUR CRITICAL STORM PATTERN

The United States Department of Agriculture Soil Conservation Service (SCS) developed dimensionless critical storm patterns using the U.S. National Weather Service's (NWS) rainfall frequency atlases (ref. 9). The rainfall frequency data for areas less than 400 square miles, for durations to 24 hours, and for frequencies from 1 to 100 years were used.

These critical storm patterns are based on the generalized precipitation depth-duration-frequency relationships shown in technical publications of the NWS and precipitation depths for durations from 1 minute to 24 hours were used to derive the storm patterns. Using increments of 30-minutes, incremental precipitation depths were determined. For example, the 30-minute depth was subtracted from the 1-hour depth and the 1-hour depth was subtracted from the 1.5-hour depth. The storm patterns were formed by arranging these 30-minute incremental depths such that the maximum 30-minute depth is contained within the maximum 1-hour depth, and the maximum 1-hour depth is contained within the maximum 1.5-hour depth and so forth. Because all of the critical precipitation depths are contained within the storm pattern, the critical storm patterns may be assumed appropriate for designs on both small and large watersheds (ref. 9).

The Agency's design storm pattern is based upon a modification of the SCS 24-hour storm pattern. The design storm pattern provides a representation of local precipitation depth-duration-frequency tendencies by constructing the several nested intervals to fit local recorded rainfall data. Additionally, the SCS storm pattern is further modified to include the necessary adjustments (reduction in shorter duration point precipitation values) due to watershed areal effects. The procedures used to construct the 24-hour storm pattern and determine the associated rainfall depths (adjusted for depth-area) follow the U.S. Corps. of Engineers methods as published in the HEC Training Document No. 15 (ref. 3). Details of the 24-hour storm pattern and the necessary adjustments for depth-area effects (indexing) are contained in Section E.

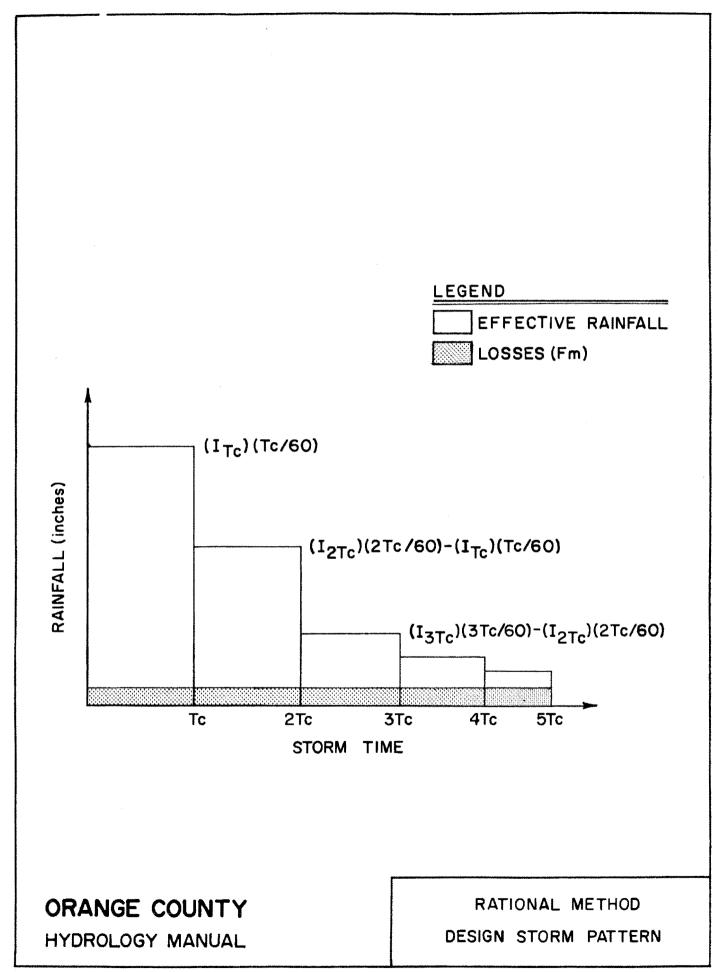
APPENDIX III

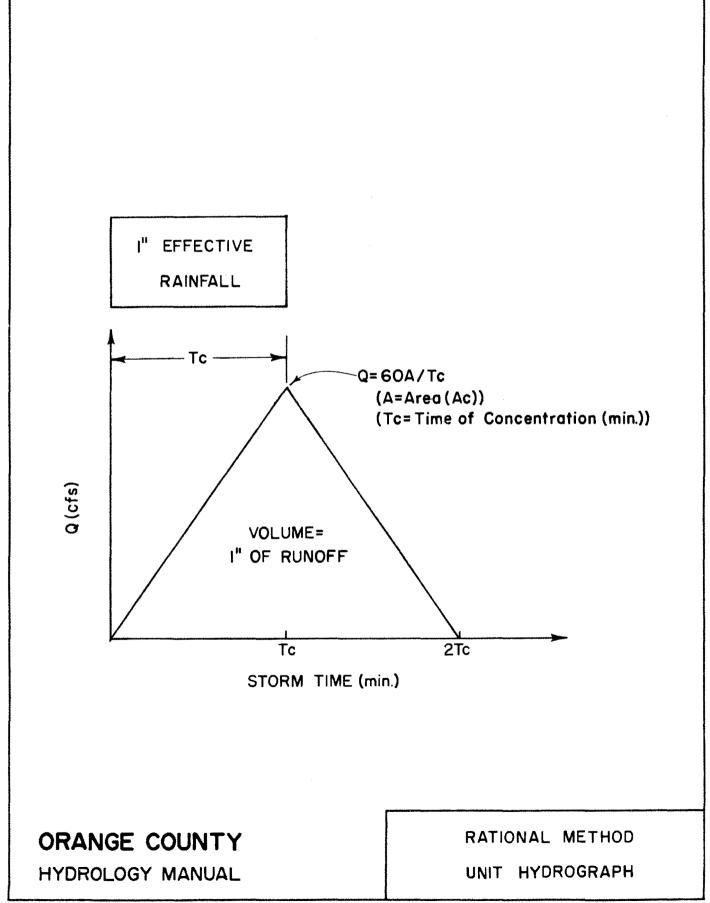
THE RATIONAL METHOD AS A DESIGN STORM UNIT HYDROGRAPH METHOD

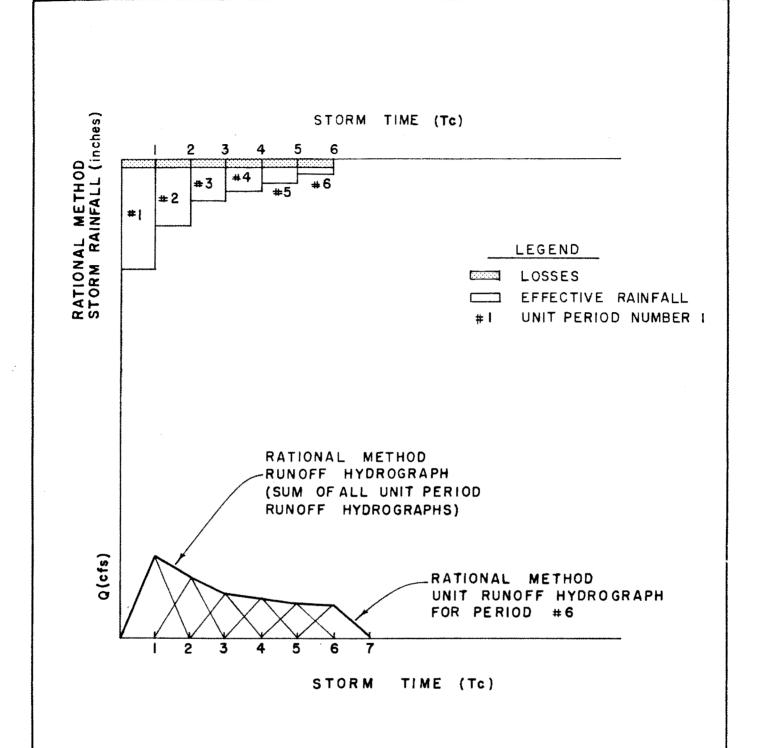
The rational method can be interpreted as a design storm unit hydrograph method. The design storm pattern is developed by using a selected return frequency rainfall intensity – duration curve. At a point of concentration with time of concentration, Tc, the rational method design storm pattern is constructed from an intensity duration curve by first determining the total amount of rainfall (i.e., unit rainfalls) which falls in several successive unit periods, each of duration Tc. The next step is to arrange these several unit rainfalls into the rational method design storm pattern (see Figure III-1) by placing the largest unit rainfall as the first unit, followed by the second largest unit rainfall, and so forth until a sufficiently long design storm pattern is developed (usually about 1-hour in total length, but may be longer depending on the various stream confluence Tc values).

Using the area-averaged loss rate F_m (e.g., see Table D.1), the design storm unit effective rainfalls are calculated by subtracting the appropriate proportion of F_m from each unit rainfall. It is noted that the design storm unit rainfalls are given in units of inches of precipitation whereas F_m is given as a rate (inch/hour).

The unit hydrograph corresponding to the rational method is a triangle with base 2Tc, and a peak occurring at time Tc (see Figure III-2). For a unit period of duration equal to Tc and a unit effective rainfall of 1 inch, the associated unit period runoff hydrograph must have a peak flow rate of (60/Tc) cfs per acre where Tc is given in minutes. Similarly, a unit period effective rainfall of only 1/2-inch must have an associated unit period runoff hydrograph with a base of 2Tc and a peak flow rate of (1/2)(60/Tc) cfs per acre. The runoff hydrographs associated to each unit effective rainfall are determined similarly, and then arranged as shown in Figure III-3 so that the resulting unit period runoff hydrographs correspond in timing to the proper unit period effective rainfalls. The runoff hydrograph is developed by adding the flow contributions from the several unit period runoff hydrographs.







ORANGE COUNTY
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RUNOFF HYDROGRAPH DEVELOPMENT

APPENDIX IV

DETENTION BASIN CONSIDERATIONS

Generally, the main purpose for inclusion of a stormwater detention basin in a flood control system is to reduce peak rates of runoff generated from an upstream watershed and to control peak flows into downstream areas. Some of the advantages and disadvantages of use of detention basins are listed in the following:

BENEFITS

- o Reduce peak rates of runoff to downstream areas.
- o Basin reduces transport of sediments carried in floodwaters.
- Reduces size of downstream flood control facilities.
- o Provides location for groundwater recharge if aquifer contact exists.
- Provides location to concentrate floodwaters for contaminant treatments.

POTENTIAL CONCERNS

- o Detention basins do not reduce total storm runoff volume (unless the groundwater recharge potential is large).
- Maintenance of storage capacity, inflow and outflow facilities is critical.
- o Basins increase the duration of flows which may increase erosion effects downstream from the basin. Downstream erosion may be further increased due to sediment extraction in the basin.
- o Improperly sized and placed basins may aggravate rather than reduce downstream flooding potential (especially in large complex systems).
- Accumulated debris from runoff decreases flood control storage volume in a detention basin.
- Cost of debris removal.
- Detention basins in urban areas may become unsightly and/or vermin infested without intensive maintenance.

The consideration of a detention basin system needs to address the various hydrologic, hydraulic, environmental and flood control concerns listed above, as well as any other concern which may arise during the course of the project study, and determine the necessary mitigative measures which are acceptable to the Agency. Of special concern is the interplay between the several components of the total system network. Unplanned placement of detention basins without consideration of other watershed detention basins and tributary watersheds can increase the downstream peak flow rate above the anticipated runoff peak flow rate attained without any detention basins in the watershed.

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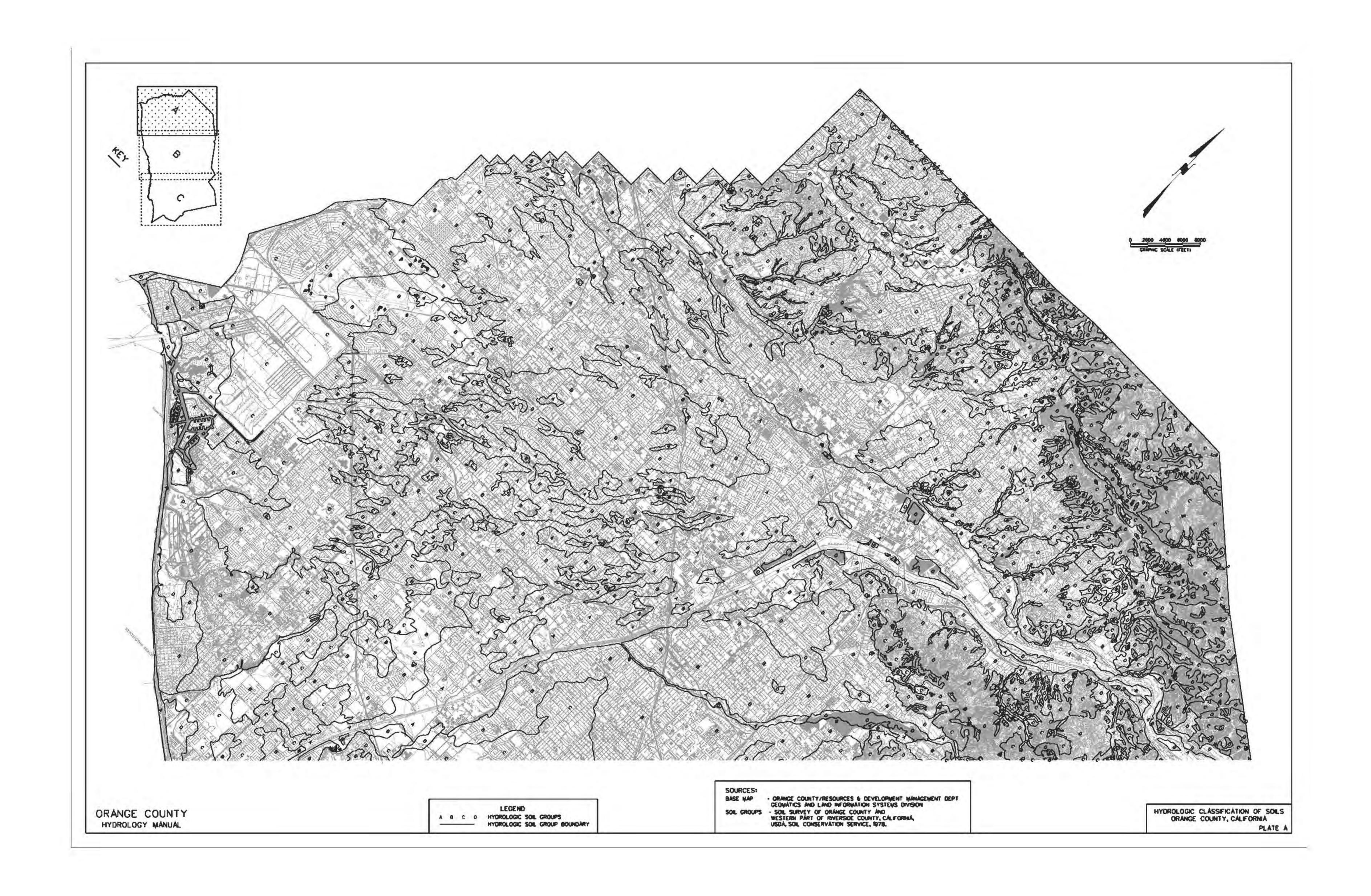
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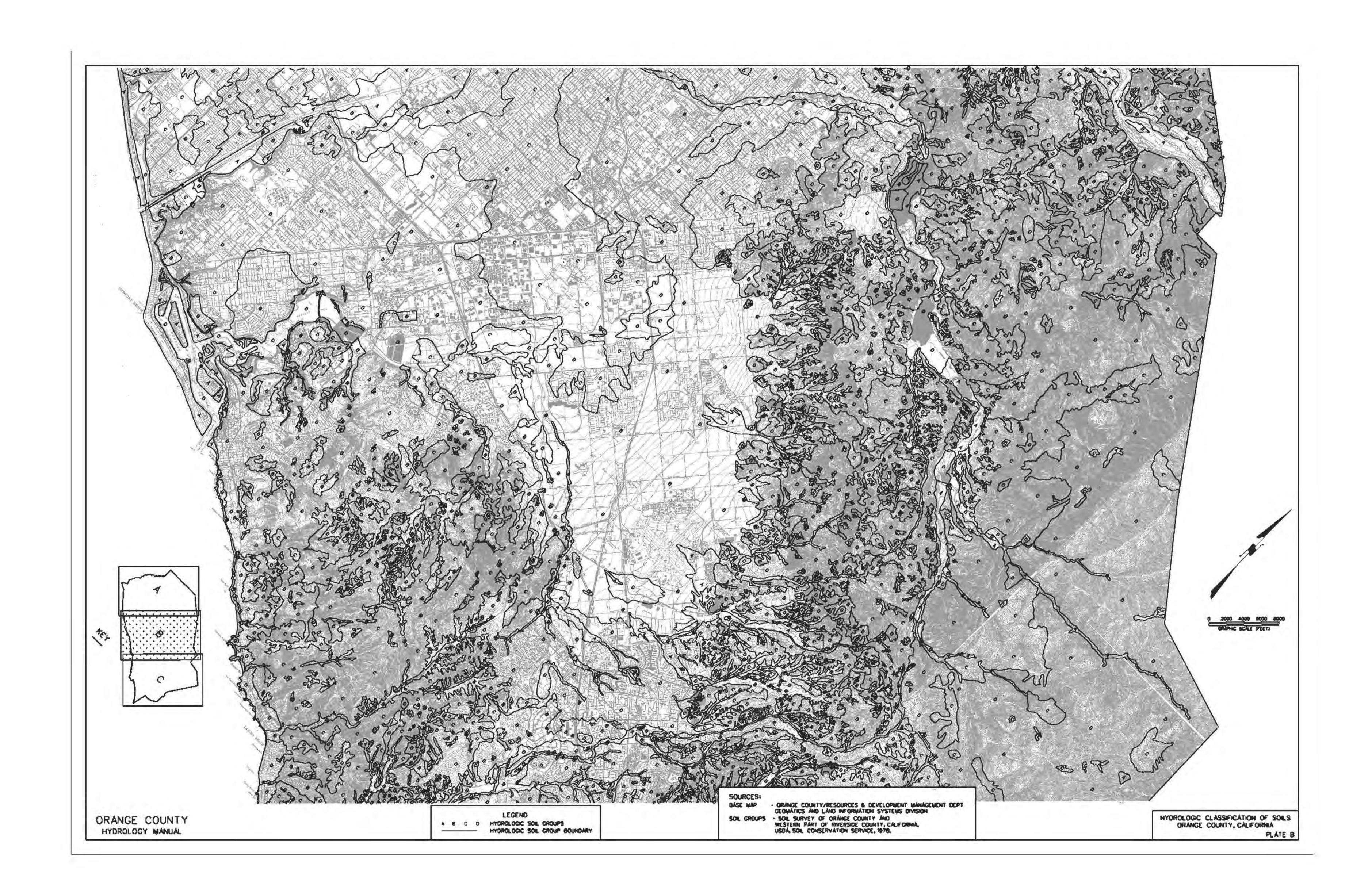
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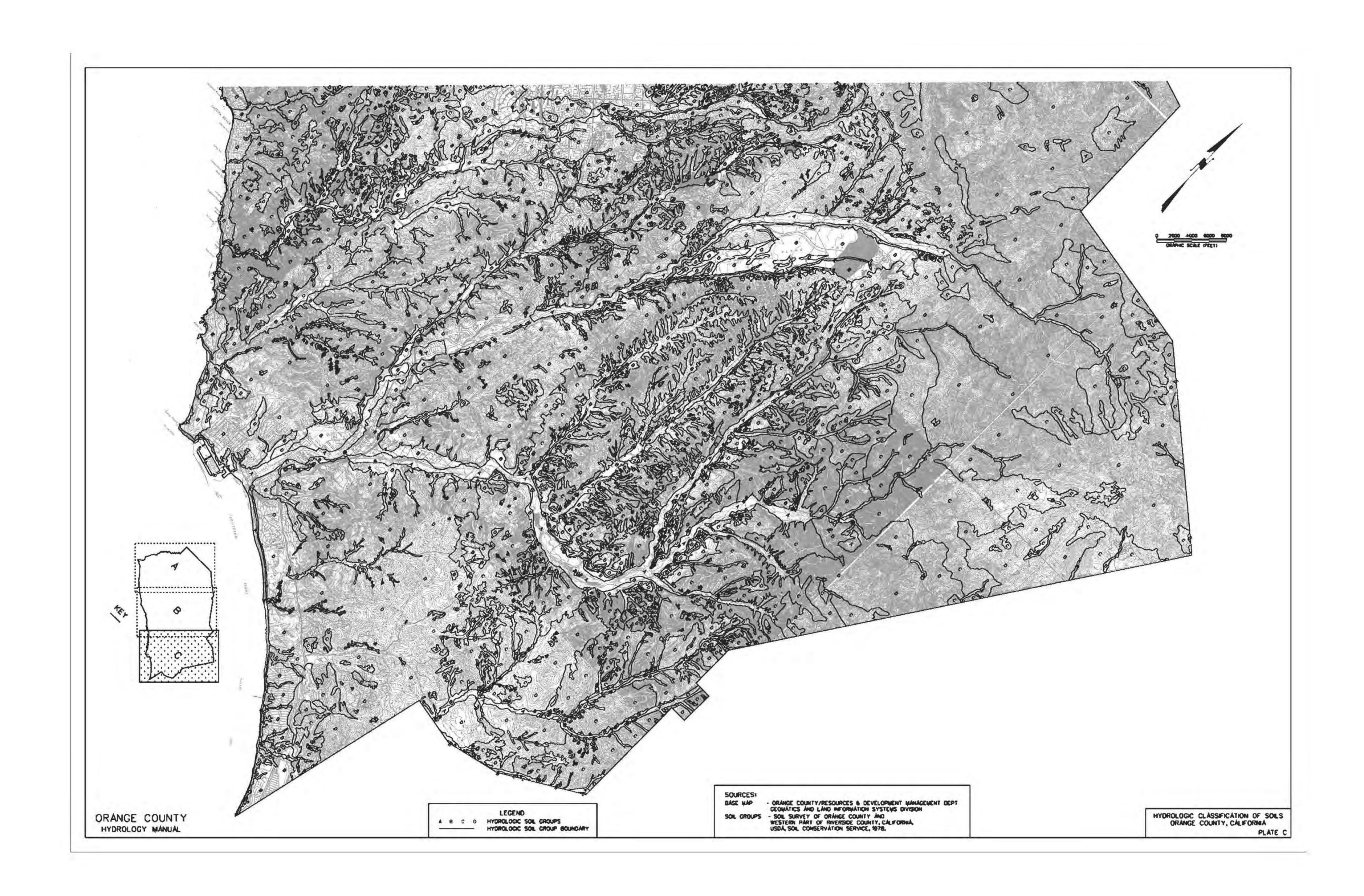
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APPENDIX V

ORANGE COUNTY HYDROLOGY MANUAL ADDENDUM NO. 1

INTRODUCTION

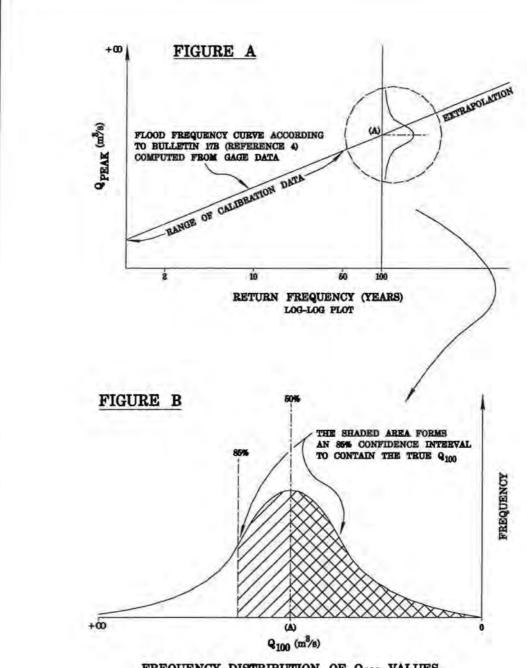
The criteria and methods used in the 1986 Orange County Hydrology Manual (hereinafter "Manual") yield high confidence (85% confidence interval) peak discharges and volumes that are appropriate for most flood control design purposes. The Manual parameters were originally based on a regional calibration study that was subsequently expanded by the U.S. Army Corps of Engineers in "Derivation of a Rainfall-Runoff Model to Compute N-Year Floods for Orange County Watersheds", November, 1987¹ and by Williamson and Schmid in "Determination of 500-Year Floodplain, Confluence of San Diego Creek and Sand Canyon Wash", March 12, 1991². There are special circumstances where such high confidence discharges may not be appropriate. This addendum establishes criteria for the use of expected value (50% confidence interval) peak discharges for design under such circumstances. Figures A and B show the definition sketches for 85% and 50% confidence intervals.

The addendum provides new guidelines for use of the initial area nomograph (Manual Figure D-1) for both high confidence and expected value calculations.

CRITERIA FOR SELECTING EXPECTED VALUE DISCHARGES

Expected value (50% confidence interval) discharges should be used for the following:

- Calculating incremental increases in peak discharge for purposes of implementing development mitigation requirements.
- · Flood plain delineations under existing conditions.
- Estimation of water resources related variables such as sedimentation and water quality.
- Evaluating protection level provided by existing facilities.



FREQUENCY DISTRIBUTION OF Q₁₀₀ VALUES (VARIATION IN Q₁₀₀ VALUES DUE TO SAMPLING EEROE)

ORANGE COUNTY
HYDROLOGY MANUAL



ADDENDUM NO.1
DEFINITION SKETCHES FOR
85% AND 50% CONFIDENCE INTERVALS

The Manual's criteria and parameter values remain in force for development proposals, subdivision improvement plans and regional flood control design as described herein. On an individual basis and where appropriate, expected value (50% confidence interval) discharges may be authorized by the Chief Engineer, Public Facilities and Resources Department for design and reconstruction of flood control facilities. However, under no circumstance should the design discharge be less than the Federal Emergency Management Agency's 100-year discharge, where such FEMA discharge is known and/or available.

CONFIDENCE INTERVAL: WHAT IT MEANS

A regional calibration considering the relationship between measured rainfall and measured peak discharges on seven Southern California watersheds was accomplished in order to determine the rainfall data to be used in the County's hydrologic models. This relationship between rainfall and peak discharges expressed in a statistical regression equation yields an "expected value" for each required recurrence interval (N-year) peak discharge (Figure A). On a regional basis half of the peak discharges calculated with these calibrated parameters would be less than the expected value and the other half would be greater than the expected value, whereas with 85% confidence interval, only a 15% probability exists for the N-year peak discharge to be exceeded. Further a probability always remains that the true N-year peak discharge may be larger or smaller than the peak discharge calculated for a given confidence interval.

MITIGATION OF DEVELOPMENT EFFECTS ON RUNOFF

The need to mitigate effects of increased runoff from developments on downstream segments of watersheds has made it necessary to consider the more frequently occurring storm flows (e.g., 2-year and 5-year). The criteria in the present Manual, mainly aimed at predicting 100-year peak discharges, is not well suited to analyze more frequently occurring storm flows that are used for mitigation. Table 2 provides the loss rate and precipitation model input required for regionally calibrated expected value 2-year and 5-year results.

LOSS RATE CALCULATIONS AND PRECIPITATION MODEL INPUT

Table I presents the T-year precipitation required to obtain the N-year expected value peak discharges for $F_p = 7.6$ mm/hr (0.3 in/hr) and AMC-II condition. The pervious loss rates (F_p) using AMC-II for 2-year and 5-year events will be 15.2 mm/hr (0.6 in/hr) and 12.7 mm/hr (0.5 in/hr) respectively, based on "Investigation of Mitigation Needs for Changes in Duration Floodflows Due to Development" by Williamson and Schmid, July, 1989³ (see Table 2).

INITIAL SUBAREA NOMOGRAPH

After extensive review within the County and with other agencies, the maximum distance of unchannelized flow over lawns and parking lots will be limited to 100 m (330') in developed areas, i.e., residential subdivisions and commercial lots. In well defined arroyos, a maximum length of 100 m may be used. The initial subarea nomograph (Manual Figure D-1) with the maximum length limit of 300 m (1000') should only be used, after appropriate justification, for flat areas such as farmland with conservation tillage, artificial surfaces like baseball/football fields, public parks, and other similar conditions.

The initial subarea nomograph, (Manual Figure D-1) which applies to both high confidence and expected value calculations, should never be used for the blueline streams shown on USGS 1:24000 quadrangle maps.



-year Precipitation Required From I ssuming a Pervious Loss Rate F _p =	
Expected Value N-year Runoff	T-Year Precipitation Model Input
10	5
25	10
50	15
100	25
500 ⁶	125 ⁶



Expected Value N-Year Runoff	Pervious Loss Rate F _p AMC-II	Proportion of N-Year Precipitation Model Input
2-yr	15.2 mm/hr (0.6 in/hr)	0.7
5-yr	12.7 mm/hr (0.5 in/hr)	0.7

Notes:

- a. Table 1 is derived from "Derivation of a Rainfall-Runoff Model to Compute N-Year Floods for Orange County Watersheds", U.S. Army Corps of Engineers, Los Angeles District, November, 1987 (Reference 1).
- b. Values have been extracted from "Determination of 500-Year Floodplain, Confluence of San Diego Creek and Sand Canyon Wash", Williamson and Schmid, March 12, 1991 (Reference 2).
- c. Table 2 is derived from "Investigation of Mitigation Needs for Changes in Duration Floodflows Due to Development", Williamson and Schmid, July, 1989 (Reference 3) and may be used for 2 and 5-year existing conditions estimates.

CONCLUSION

Notwithstanding Addendum No. 1, Manual criteria and parameter values remain in force for development proposals, subdivision improvement plans and regional flood control design, except for the initial area nomograph changes as discussed above.

REFERENCES

- "Derivation of Rainfall-Runoff Model to Compute N-Year Floods for Orange County Watersheds", U. S. Army Corps of Engineers, Los Angeles District, November, 1987.
- "Determination of 500-Year Floodplain, Confluence of San Diego Creek and Sand Canyon Wash", Williamson and Schmid, March 12, 1991.
- "Investigation of Mitigation Needs for Changes in Duration Floodflows Due to Development", Williamson and Schmid, July, 1989.
- "Guidelines for Determining Flood Flow Frequency, Bulletin 17B", U. S. Department of the Interior, Geological Survey, Office of Water Data Coordination, revised September 1981.



APPENDIX K



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Stanton Energy Reliability Center Stanton Storm Channel Hydraulic Technical Memorandum

Background

WSP | Parsons Brinckerhoff (PB) is providing civil design support for the Stanton Energy Reliability Center which includes analysis of the Stanton Storm Channel to meet requirements of the encroachment permit application. The project proposes to construct a vehicle bridge and a utility bridge over the channel, which requires analysis of the hydraulic impacts to the 100 year water surface. Previous studies have provided a design 100 year flow rate of 729 cfs for the channel reach in question.

Purpose

The purpose of this technical memorandum is to quantify the existing 100 year water surface in the Stanton channel and quantify impacts from construction of two proposed bridges over the channel on the 100 year water surface.

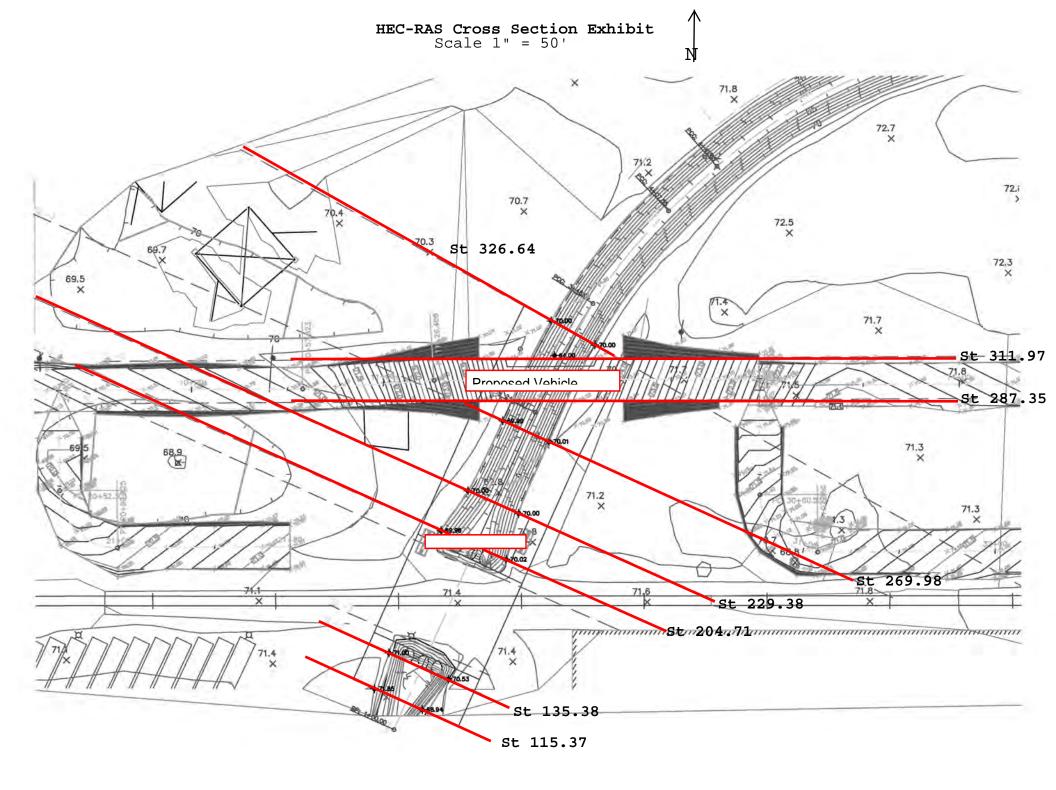
Methodology

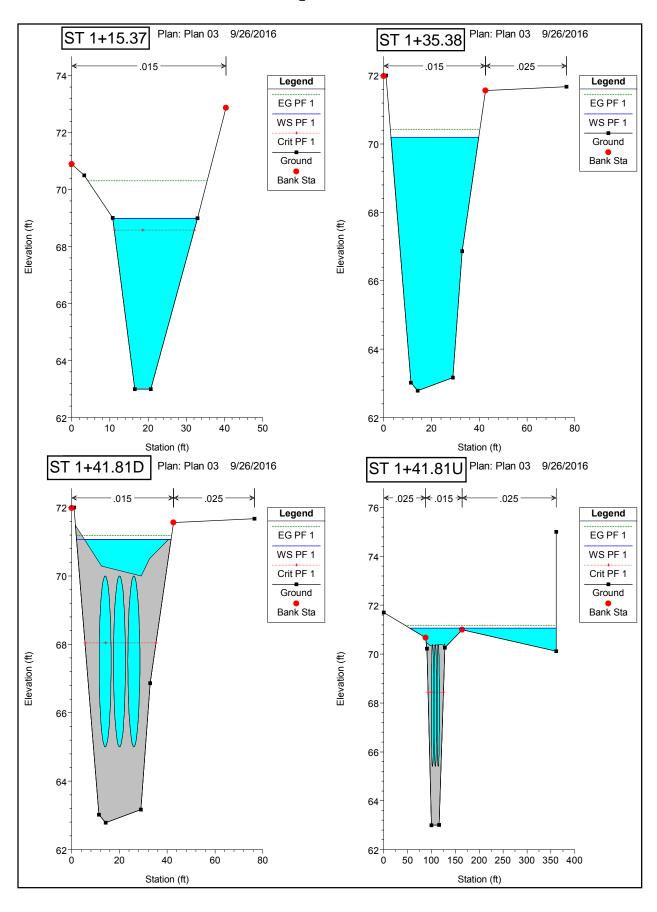
The design 100 year flow rate was taken from the Hydrology Report for Bolsa Chica Channel Facility No C02, dated March 2015, prepared by Orange County Department of Public Works for he node designated as 5.11. Channel geometry was based on topography from the ALTA survey. Located under the existing railroad just downstream of the site, the triple pipe culvert elevations were based on the 1994 Parcel 2 drainage facility elevations and 2 feet was added to accommodate the difference in benchmark between as-builts and the ALTA survey. Hydrologic Engineering Center River Analysis System (HEC-RAS) was used to perform computations. Sections were cut using AutoCAD and then imported into HEC-RAS. Stationing was developed independent of the Stanton Channel stationing but for conversion purposes River Station 253+06.45 = 3+00 in the HEC-RAS model. The existing condition was modeled with 8 sections (1+15.37, 1+35.38, 2+04.71, 2+29.38, 2+69.98, 2+87.35, 3+11.97 & 3+26.54). The proposed condition used the same number of sections but included a vehicle bridge between 2+87.35 and 3+11.97 and a utility bridge between 2+04.71 and 2+29.38. Water surface elevations were then compared to quantify the impact of the proposed bridges.

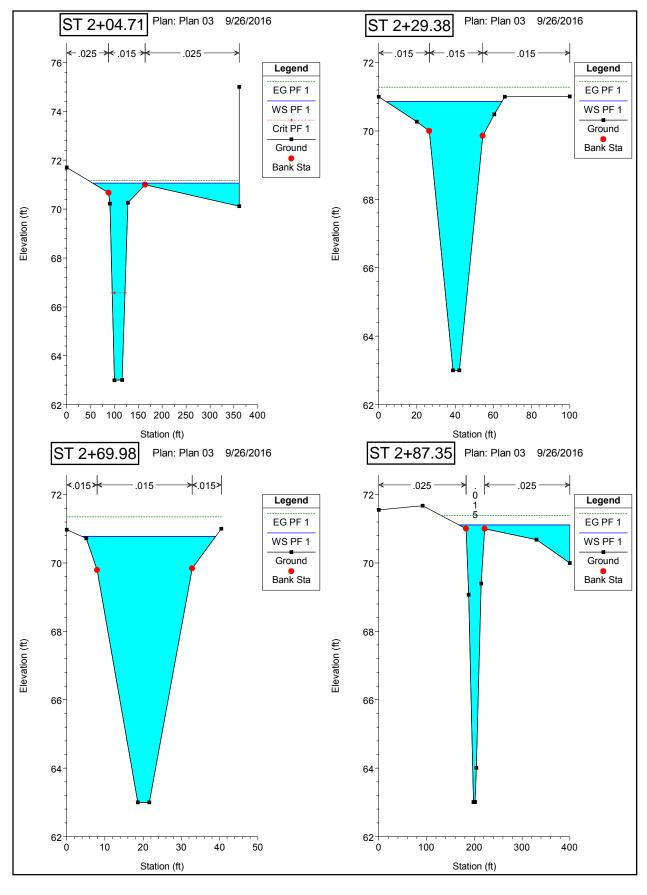
Results

The water surface was calculated for existing and proposed conditions based on a mixed flow regime, whereby calculations were performed for subcritical and supercritical conditions and the most conservative water surface was then used. The existing condition and proposed condition summary table is provided below. The maximum proposed 100 year water surface elevation is 71.33 ft. 3.9 ft of freeboard is provided between the 100 year water surface and the utility bridge bottom of steel and 1.2 ft is provided between the 100 year water surface and the vehicle bridge bottom of steel.

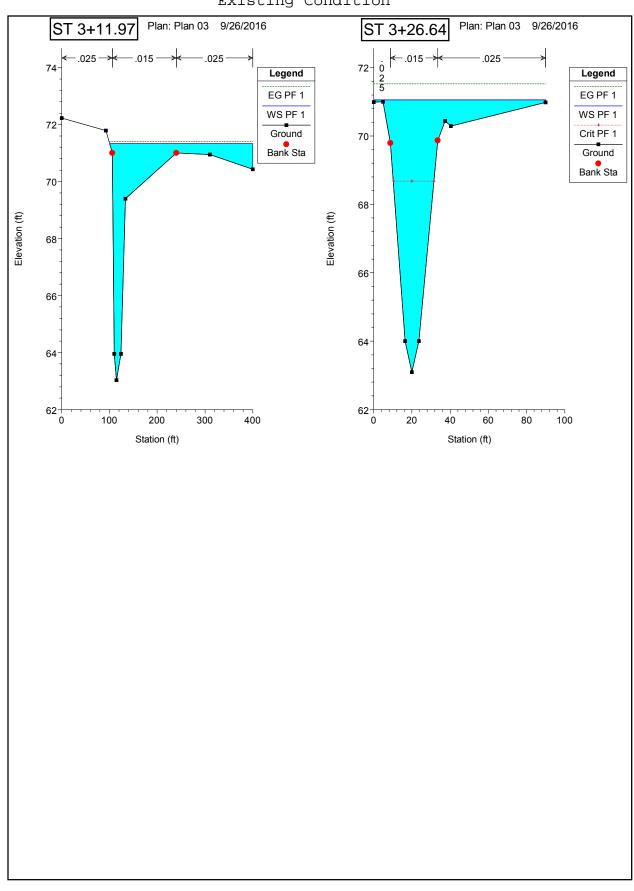
Existing vs Proposed Water Surface Summary Table			
River Station	Q Total	Existing W.S. Elev	Proposed W.S Elev
(ft)	(cfs)	(ft)	(ft)
326.64	729	71.06	71.06
311.97	729	71.32	71.33
287.35	729	71.11	71.11
269.98	729	70.77	70.77
229.38	729	70.86	70.86
204.71	729	71.07	71.07
135.38	729	70.2	70.2
115.37	729	68.98	68.98

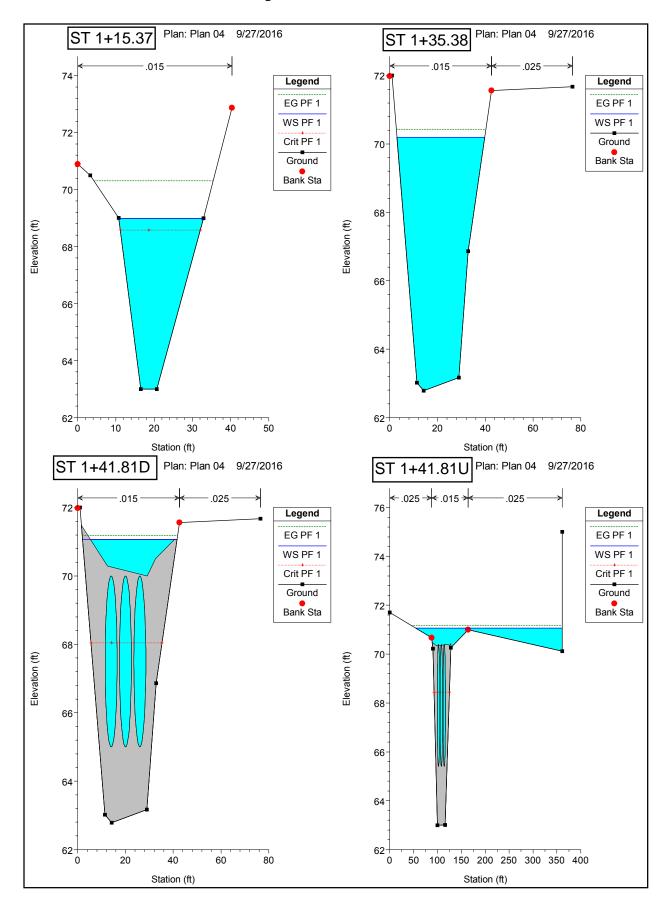


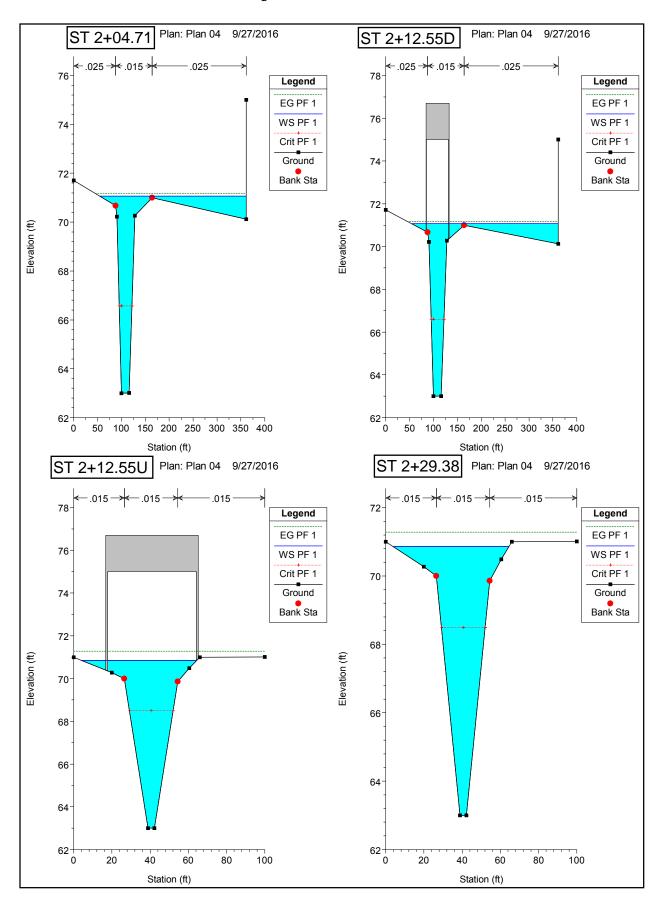


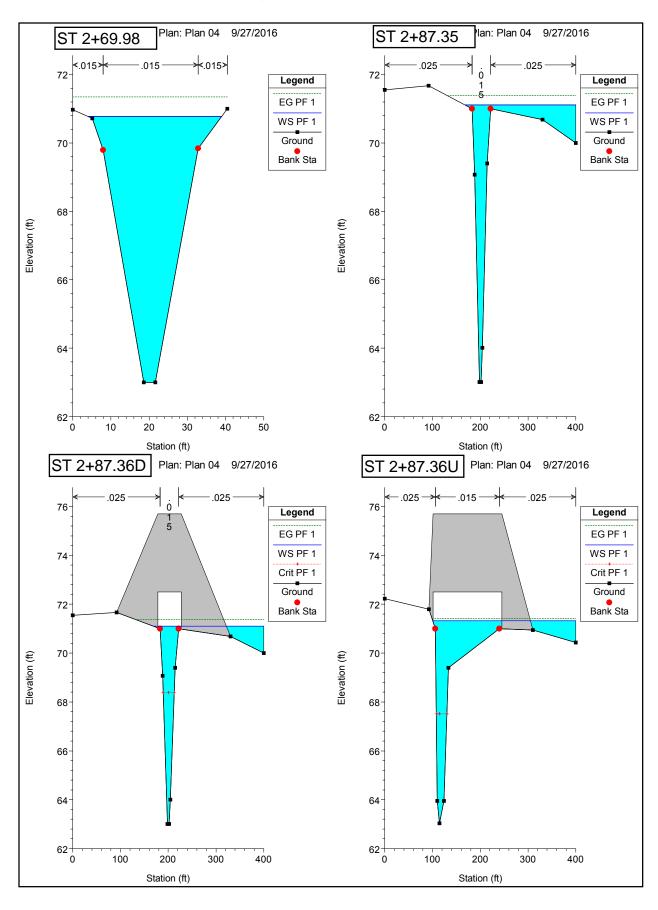


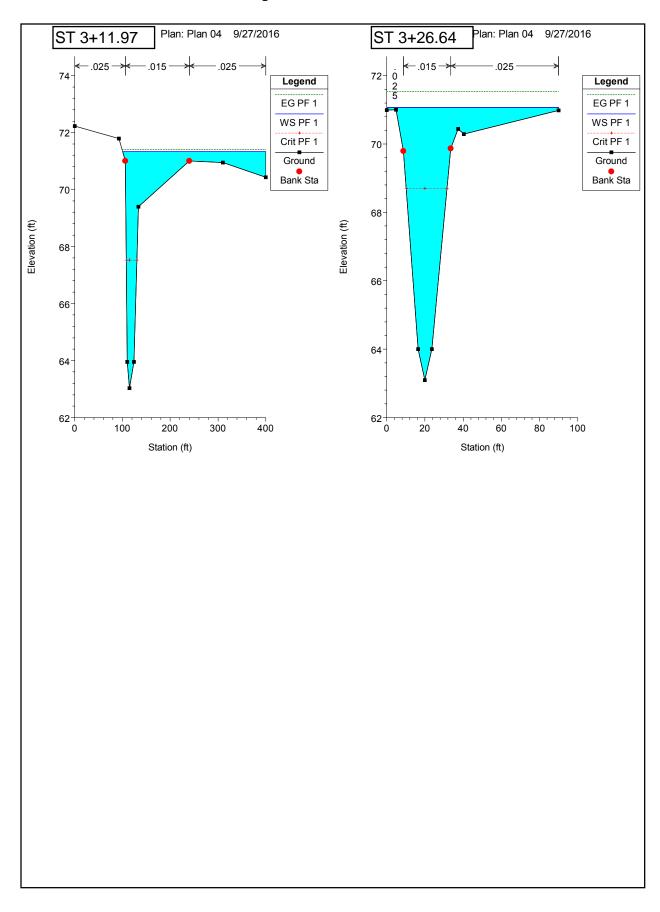
Existing Condition













APPENDIX L

