Professional Engineering Exam

Water Resources and Environmental Engineering

Study Guide

Education and Training Evaluation Commission (ETEC)
National Center for Assessment (NCA)

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Table of Contents

1. Aim:

The objective of this Instruction Manual is to provide guidelines for the NCA proposed Professional Engineers Exam. These guidelines cover the eligibility conditions, the grading and passing conditions, the structure of the exam and the distribution of exam questions among various areas. In essence, this Instruction Manual represents a “bridge” between the developed exam standards and the actual phrased questions. It is designed to help item writers prepare questions for the Water Resources and Environmental Engineering Discipline Exam as well as a study guide for examinees.

2. Exam Structure:

2.1 Exam Type

The exam is initially paper-based with questions being a combination of multiple- choice questions (MCQ) and essays.

2.2 Exam Organization

The exam will be conducted in two sessions during one day. The duration of the first session is 2.5 hours while the second section is 4 hours long. There is one-hour break between the two sessions.

2.2.1. Session #1

The first session is the common part to be taken by all the examinees from all disciplines. This part includes seven topics: (Ethics – Professionalism - Laws for Professional Practice, Professional Laws and Regulation - Environment and Natural Resources - Engineering Management - Engineering Economics - Health, Safety & Security (HSS)).

The total duration of this session is 2.5 hours and the total number of questions is 30 MCQ and 2 essays.

2.2.2. Session #2

The second session is the Discipline Part. The following engineering disciplines are considered:

Code	Discipline
STE	Structural Engineering
GTE	Geotechnical Engineering
TRE	Transportation Engineering
WREE	Water Resources and Environmental Engineering
PE	Power Engineering
HVAC	Heating, Ventilation, and Air Conditioning (HVAC) and Refrigeration Engineering
TFSE	Thermal and Fluids Systems Engineering
CHE	Chemical Engineering
FPE	Fire Protection Engineering
ARCH	Architecture

The total duration of this session is four hours and the total number of questions is 30 MCQs and four essays. The examinee must answer all the MCQs and two essays out of four.

2.3 Eligibility for the Exam

The eligibility to register for the exam is according to the Saudi Council of Engineers (SCE) requirements.

2.4 Grades

Each part (common part and discipline part) carries a grade of 100. The MCQ carry a grade of 60% while the essays carry a grade of 40%. Each MCQ has 4 choices for the answer. There is no negative marking for wrong answers.

2.5 Passing Rules

- The eligible candidate must take in his/her first sitting the two exam parts (common part and discipline part).
- In order to pass the exam, the candidate must obtain a grade of 60% or above in each part of the exam.
- If the candidate fails both parts of the exam (by receiving in each part a grade less than 60%), he/she can take the two parts of the exam but only when one full year has passed.
- If the candidate fails only one part of the exam (common part or discipline part), he/she must repeat only the part he/she failed, but he/she must pass this part within one year.
- If a year passed and the candidate did not succeed in passing the part he/she failed, then he/she has to take both parts of the exam

2.6 Exam Rules

- No printed or electronic material is allowed during the exam. All necessary reference materials will be provided by NCA.
- Calculators approved by NCA are allowed.
- Comprehensive exam rules will be provided by the examination authority, NCA, in a separate manual.

3. Table of Specifications for NCA Professional Engineers Exam: Water Resources and Environmental Engineering:

Major Area	Multiple Choice Questions (MCQs)		Number of Essay Questions	Engineering Standard
	% of Test	Number of Questions		
1. Fluid Mechanics, and Open Channel and Pipe Flow Hydraulics	10%	3	The engineer will choose two essay questions out of four	WREE-T1
2. Surface and Groundwater Hydrology	10%	3		WREE-T2
3. Design of Hydraulic Structures	10%	3		WREE-T3
4. Water Resources Planning and Management	6.7%	2		WREE-T4
5. Desalination Plants and Coastal Works Design and Assessment	10%	3		WREE-T5
6. Water Treatment, Supply & Reuse	6.7%	2		WREE-T6
7. Sewerage Management, Treatment and Reuse	6.7%	2		WREE-T7
8. Solid & Hazardous Waste Management (Including Domestic and Industrial Wastes)	6.7%	2		WREE-T8
9. Air Quality Management	6.7%	2		WREE-T9
10. Environmental Planning, Monitoring and Management	6.7%	2		WREE-T10
11. Environmental Risk and Performance Management Modeling	6.7%	2		WREE-T11
12. Feasibility Assessment and Project Management	6.7%	2		WREE-T12
13. Environmental Laws, Codes and Standards	3.3%	1		WREE-T13
14. Simulation and Modeling Programs	3.3%	1		WREE-T14
Total	100%	30	2 essays out of 4	

4. Standards for Water Resources and Environmental Engineering:

The Engineering Standards for the Water Resources and Environmental Engineering (WREE) Discipline are structured in 14 major topics that are below listed (WREE-T1 to WREE-T14). Each major topic has certain indicators or sub-topics that are below defined. Professional Engineers in the WREE Discipline are expected to possess and demonstrate command of these major topics in the WREE practice.

WREE-T1: Fluid Mechanics, and Open Channel and Pipe Flow Hydraulics

WREE-T1-1 Apply theories and principles of hydrodynamics and flow equations; for example, mass, energy and momentum conservation principles, to solve water-related problems.

WREE-T1-2 Determine the possible water surface profiles along channels under different flow conditions; including steady, unsteady, uniform and non-uniform conditions.

WREE-T1-3 Design open channel conduits given specific constraints; e.g. most economic cross-section for rigid-boundary channels, and non-silting non-scouring velocity for loose boundary channels ...etc.

WREE-T1-4 Estimate scour depths and sediment transport rates in streams, and propose erosion sediment control plans/measures.

WREE-T1-5 Model open channel and pipe flows using common simulation programs; including steady/unsteady state and extended/continuous period simulations.

WREE-T1-6 Design transmission pipelines and pipe networks; including selecting appropriate pumps, design of pump stations, and pipe material selection where necessary.

WREE-T1-7 Assess transient pressures in pipelines and design countermeasures to reduce water hammer effects.

WREE-T1-8 Assess buoyancy and stability of floating and submerged solid bodies in fluids and determining hydrostatic and hydrodynamic forces on surfaces; for example, on gates, tanks, elbows and bends.

WREE-T2: Surface and Groundwater Hydrology

WREE-T2-1 Recognize the available water resources in KSA, and apply water cycle management principles and techniques.

WREE-T2-2 Analyze rainfall-runoff relationships and estimate runoff from watersheds using appropriate methods.

WREE-T2-3 Estimate stormwater quality using appropriate methods and methods to improve water quality to meet the guidelines.

WREE-T2-4 Apply different flood routing methods.

WREE-T2-5 Perform statistical analyses of hydrological data; including frequency analyses of rainfall and flood data.

WREE-T2-6 Estimate water losses through evaporation and infiltration.

WREE-T2-7 Use hydrologic Instruments, Telemetry Systems and Remote Sensing.

WREE-T2-8 Apply water budget principles to estimate potential water availability.

WREE-T2-9 Identify the different groundwater aquifers along with their hydraulic characteristics.

WREE-T2-10 Apply groundwater flow principles and assess groundwater quantity and quality.

WREE-T2-11 Design sustainable groundwater withdrawal well systems in the different types of aquifers.

WREE-T2-12 Design groundwater management strategies, including but not limited to withdrawal, recharge, remediation methods ... etc.

WREE-T2-13 Assess groundwater contaminant fate and transport and verify the assessment using common available software.

WREE-T3: Design of Hydraulic Structures

WREE-T3-1 Design culverts under different flow control conditions.

WREE-T3-2 Apply the hydrotechnical design of bridges; including piers and abutments to avoid scour around them.

WREE-T3-3 Design different types of weirs.

WREE-T3-4 Design, operate, and maintain different types of dams; including reservoir design and optimization.

WREE-T3-5 Design erosion and sediment control structures; for example, stormwater ponds, dykes, spurs, guide banks, aprons, gabion baskets/mats, riprap ...etc.

WREE-T3-6 Design outfall structures; including energy dissipaters.

WREE-T3-7 Design road drainage facilities; such as, storm water drainage pipe networks, drop structures, curb inlets, gutters, storm water harvesting ponds and dewatering systems.

WREE-T3-8 Design flood control structures; including floodwalls and flood boxes.

WREE-T3-9 Assess micro to large hydroelectric power generation potential; for example, in-line pipe turbines.

WREE-T4: Water Resources Planning, Modeling and Management

WREE-T4-1	Assess the demands of the different sectors within urban and rural communities.
WREE-T4-2	Estimate the potential water supply through the different resources including surface water, groundwater, desalinized water and treated wastewater, both during existing conditions and for short- and long-term developments.
WREE-T4-3	Analyze water resources systems and optimize their use.
WREE-T4-4	Understand storm water drainage management principles and techniques.
WREE-T4-5	Assess flood risks and flood hazards, and apply flood mitigation strategies.
WREE-T4-6	Identify water allocations and water saving strategies.
WREE-T4-7	Assess water security and identify countermeasures for periods of water deficit.
WREE-T4-8	Evaluate suitable water tariffs for sustainable consumption by the different sectors.
WREE-T4-9	Estimate risk and uncertainty in water resources systems; including evaluation of alternatives and their hydrologic and hydraulic modelling, watershed modelling, and water resources economics.

WREE-T5: Desalination Plants and Coastal Works Design and Assessment Indicators

WREE-T5-1	Design intake structures, outfalls and water delivery systems in desalination plants along coastlines.
WREE-T5-2	Evaluate different desalination technologies.
WREE-T5-3	Design and assess different brine disposal methods.
WREE-T5-4	Design breakwaters for harbors considering seawater waves and undercurrents.
WREE-T5-5	Assess erosion of shorelines and design suitable countermeasures.

WREE-T6: Water Treatment, Supply and Reuse

WREE-T6-1	Apply the adopted water quality parameters and standards in KSA.
WREE-T6-2	Design different types of water treatment plants; including desalination plants and their operation under zero-liquid-discharge (ZLD) operation.
WREE-T6-3	Design water supply networks under peak demands and fire protection requirements.
WREE-T6-4	Design treatment systems for the reuse of collected storm water.

WREE-T6-5	Identify suitable flow meters for measuring water consumption in different sectors; for example, residential, commercial and industrial sectors.
WREE-T6-6	Design water distribution networks including storage facilities.
WREE-T6-7	Estimate leakage in pipes and design countermeasures to reduce leakage.
WREE-T6-8	Recognize water network management techniques; such as, Supervisory Control and Data Acquisition (SCADA) systems and Pressure Management Zoning (PMZ), District Metering Zones and District Metering Areas (DMZ/DMA).
WREE-T6-9	Recognize performance metrics in water distribution systems.

WREE-T7: Sewerage Management, Treatment and Reuse

WREE-T7-1	Design different types of municipal wastewater treatment plants.
WREE-T7-2	Design wastewater treatment facilities for various industrial facilities such as refineries, petrochemical industry, car wash facilities, desalination plants ... etc.
WREE-T7-3	Recognize and apply recent wastewater treatment technologies.
WREE-T7-4	Design wastewater treatment systems for reuse of various types of wastewaters; such as municipal and industrial wastewaters.
WREE-T7-5	Design sewerage collection system.
WREE-T7-6	Apply sewerage network management and control practices; for example, SCADA system.
WREE-T7-7	Apply sludge management/reuse practices.
WREE-T7-8	Recognize Treated Sewerage Effluent (TSE) criteria and applications.

WREE-T8: Solid and Hazardous Waste Management (Including Domestic and Industrial Wastes)

WREE-T8-1	Apply solid waste treatment technologies; for example, waste-to-energy plants, material recovery plants (MRFs) and landfills.
WREE-T8-2	Recognize the importance of applying the 3Rs of waste management; i.e. Reuse, Recover and Recycle.
WREE-T8-3	Apply cradle-to-grave principles of waste management.
WREE-T8-4	Apply safe hazardous waste management handling, storage and treatment principles for the different sectors; including industrial, medical and chemical wastes.
WREE-T8-5	Recognize Strategic Approach to International Chemical Management (SAICM).

WREE-T9: Air Quality Management

WREE-T9-1	Define air pollution and air quality indices.
WREE-T9-2	Identify air quality emission sources.
WREE-T9-3	Design air quality monitoring and treatment systems.
WREE-T9-4	Model indoor and outdoor air quality using recent software.
WREE-T9-5	Predict and assess severity of dust storms.
WREE-T9-6	Control odour and apply treatment technologies.

WREE-T10: Environmental Planning, Monitoring and Management

WREE-T10-1	Identify environmental aspects, impacts and hazards.
WREE-T10-2	Evaluate and assess environmental and ecological footprints.
WREE-T10-3	Prepare environmental monitoring and management plans.
WREE-T10-4	Perform environmental audits.
WREE-T10-5	Perform environmental site assessments (ESAs).
WREE-T10-6	Identify eco-tourism concepts.
WREE-T10-7	Assess renewable resources and design implementation plans for resource management.
WREE-T10-8	Design energy conservation models/methods.

WREE-T11: Environmental Risk and Performance Management Modeling

WREE-T11-1	Recognize the state of the environmental and ecological models.
WREE-T11-2	Identify and quantify environmental risks and liabilities.
WREE-T11-3	Identify environmental sustainability indices.
WREE-T11-4	Perform health, social, safety and environmental impact assessments (EIAs).
WREE-T11-5	Perform health, social, safety and environmental life-cycle assessment (LCAs).
WREE-T11-6	Design environmental management systems (EMS).
WREE-T11-7	Recognize the importance of carbon management.
WREE-T11-8	Assess the carbon foot print and management/reduction strategies for various operations; including municipal (landfills, water and wastewater treatment facilities, desalination plants ...etc.) and industrial (refineries, refinery wastewater treatment facility, oil & gas sector, petrochemical industry ... etc.) sectors.

WREE-T12: Feasibility Assessment and Project Management

WREE-T12-1 Identify the different constraints in a project.

WREE-T12-2 Assess the technical feasibility of different designs or alternatives.

WREE-T12-3 Assess the operational feasibility/constructability of different designs or alternatives.

WREE-T12-4 Assess the legal feasibility of different designs or alternatives.

WREE-T12-5 Assess the scheduling feasibility of different designs or alternatives.

WREE-T12-6 Perform project management strategies and suggest the best possible management options.

WREE-T12-7 Identify the risks associated in a project.

WREE-T12-8 Perform cost-benefit analysis to compare design alternatives.

WREE-T13: Environmental Laws, Codes and Standards

WREE-T13-1 Recognize the importance of water and wastewater infrastructure codes, acts, specifications, requirements and limitations; especially the Saudi ones and other similar regional or international corresponding documents where Saudi documents may not be available.

WREE-T13-2 Be familiar with the Regional Protocols and Conventions; for example, Regional Organization for the Protection of the Marine Environment (ROPME).

WREE-T13-3 Recognize and apply Saudi Environmental Laws and Standards; for example, the relevant water, sanitation and fire protection requirements chapters of the Saudi Building Code.

WREE-T13-4 Recognize and apply Saudi Water, Wastewater and Energy Legislation, Standards and Programs.

WREE-T14: Simulation and Modeling Programs

WREE-T14-1 Identify and demonstrate the use of the different simulation and modeling software/programs used in surface water flow (both open channel and pipe flows), groundwater flow, and hydraulic structures design.

WREE-T14-2 Identify and use the different simulation and modeling software/programs used in water, stormwater, and wastewater treatment.

WREE-T14-3 Identify and use the different simulation and modeling software/programs used in air quality, and solid and hazardous waste management.

5. Sample of Questions

Q. No.	Major Area	Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
1	**Fluid Mechanics, and Open Channel and Pipe Flow Hydraulics**	WREE-T1-1	Estimate the time required to discharge runoff from a watershed that generates stormwater runoff volume of approximately 31,000 m^3. Assume that the runoff will be discharged through a rectangular channel that is 1.20 m wide, 0.60 m deep and has a longitudinal slope of 0.2% and its Manning's roughness coefficient (n) is 0.022. If the channel flow is uniform at a depth of 0.45 m, then the time (hours) is nearest to: A) 10 B) 16 C) 19 D) 23	(C)	2.0 - 3.0	None
2	**Fluid Mechanics, and Open Channel and Pipe Flow Hydraulics**	WREE-T1-6	A small village has a population of 6000 inhabitants. The daily water demand of the residents is estimated to be 150 l/c/d. A pump station is located near a river, such that the static head for all the pumps is 100 m. The pumps are to deliver river water to the village, and the available pumps from the closest dealer are 10-horsepower each with an efficiency (σ) of 70%. Assuming the head losses are 15% of the static head, the closest required number of pumps; given that they will be connected in parallel in the pump station and that their operating time is only 6 hours/day, would be: A) 3 B) 5 C) 9 D) 12	(C)	5.0 - 6.0	Pump horsepower $= p = \frac{\gamma Q h_p}{750 * \sigma}$ Where: γ = specific weight of water (N/m^3) Q = discharge (m^3/s) h_p = pump head (m)

<table>
<tr><th>Q. No.</th><th>Major Area</th><th>Code</th><th>Question Statement
(Answer's Choices)</th><th>Key Answer</th><th>Expected Time (min.)</th><th>Supplied Reference</th></tr>
<tr><td>3</td><td>Surface and Groundwater Hydrology</td><td>WREE-T2-10</td><td>Three groundwater wells; A, B, and C, are located such that the spacing between any two of them is 500 m. The following data are given for the wells:
<table><tr><th>Well Label</th><th>Ground El. (m)</th><th>Well Base El. (m)</th><th>Water Pressure Head at the Well Base (m)</th></tr><tr><td>A</td><td>150</td><td>50</td><td>32</td></tr><tr><td>B</td><td>120</td><td>38</td><td>45</td></tr><tr><td>C</td><td>175</td><td>50</td><td>27</td></tr></table>
The hydraulic gradient (i) for the flow potential between wells A and B is:

A) 0.002
B) 0.010
C) 0.012
D) 0.020</td><td>(A)</td><td>4.0 - 5.0</td><td>None</td></tr>
<tr><td>4</td><td>Design of Hydraulic Structures</td><td>WREE-T3-5</td><td>An 18-inches circular culvert discharges 24 cfs onto a grassy embankment that has no defined channel. The minimum apron length, L_a, (ft) and minimum d_{50} (inches) of the required riprap at the culvert outlet to prevent erosion are closest to:

A) 13 ft, 8 inches
B) 20 ft, 9.6 inches
C) 22 ft, 12 inches
D) 25 ft, 15 inches</td><td>(B)</td><td>3.0 – 4.0</td><td>See the attached design charts at the end of the Solutions Section</td></tr>
<tr><td>5</td><td>Surface and Groundwater Hydrology</td><td>WREE-T2-8</td><td>The six-month seasonal precipitation on a small watershed is 70 cm, the runoff is 20 cm, and the change in groundwater storage is 15 cm. What is the average monthly evapotranspiration rate (cm/month), assuming no initial abstraction?

A) 5.83
B) 20.24
C) 35.56
D) 65.23</td><td>(A)</td><td>2.0 – 3.0</td><td>None</td></tr>
</table>

Q. No.	Major Area	Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
6	**Water Treatment, Supply and Reuse**	WREE-T6-9	What is the average monthly NRW (non-revenue water) in the case of a water company having an offtake agreement with a distribution company to supply into the system inlet reservoirs a daily quantity of 2,000,000 m3/day? This water is supplied 50% from underground aquifers using RO with an average reject rate of 65%. The distribution supply network has average commercial losses of 500,000 m3/day and physical losses of 700,000 m3/day. The monthly quantity of bills issued and collected by registered customers is equivalent to 45 million m3/month. So, the average monthly NRW is: A) 25 % B) 50 % C) 75 % D) 100 %	(A)	3.0 – 4.0	None
7	**Sewerage Management, Treatment and Reuse**	WREE-T7-7	An extended aeration tank, which is operated as continuous mixed reactor with length 50 meters, 20 meters wide and a hydraulic level of 4 meters deep, requires a sludge age of 10 days to achieve a MLSS of 2,500 mg/l. What is total volume of sludge (in m3) withdrawn per day, if the average daily feed is 1,000 m3/day? A) 200 B) 400 C) 8,000 D) 1,000	(B)	3.0 – 4.0	None
8	**Air Quality Management**	WREE-T9-1	Does the impact of higher ambient air temperature on the air quality increase or decrease the Yale Environmental Pollution Index? A) Higher temperature increases the Yale Environmental Pollution Index because of higher rate of evaporation of any hazardous volatile components in the air. B) Higher temperature decreases the Yale Environmental Pollution Index because of the higher rate of evaporation of any hazardous volatile components in the air.	(D)	3.0 – 4.0	None

Q. No.	Major Area	Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
			C) There is no change to the Yale Environmental Pollution Index because the calculation factors in variance in ambient air temperature. D) Not possible to answer because it would depend on the type of air quality contaminants and knowledge of meteorological data such as humidity, and windrose data.			
9	**Air Quality Management**	WREE-T9-3	What is the best description from the list below that describe the BPEO / BATNEEC principles for Flue Gas Desulphurisation System (FGD)? A) Fluidized Incineration / wet air oxidation. B) Radiation technology. C) Limestone forced oxidation. D) Physical chemical scrubber separation.	(D)	3.0 – 4.0	None
10	**Environmental Risk and Performance Management Modeling**	WREE-T11-2	What are the main risks in designing a co-compost facility to treat domestic and sewage wastes? A) Domestic waste generally has a low percentage (less than 30 % of organic biodegradable wastes). B) There is a need to have an initial good performance from a materials recycling facility to separate the domestic wastes (organic from non-organic wastes). C) There is need to have a good pretreatment and monitoring of all wastes prior to co-composting. D) The risk will not be meeting the Ministry of Agriculture, Water and Environmental standards for reuse of composting for agricultural land use.	(C)	3.0 – 4.0	None
Essay # 1	**Design of Hydraulic Structures**	WREE-T3-6	A 1200-mm diameter concrete end sewer discharges the storm runoff from a small town into a narrow wadi edging the town. The sewer is designed to convey the 100-year storm discharge estimated at 6 m3/s while flowing 1/2 full. Discuss the suitability of the sewer material and any necessary requirements to ensure its durability if the material cannot be changed. Also, describe	-	30 min	None

Q. No.	Major Area	Code	Question Statement (Answer's Choices)	Key Answer	Expected Time (min.)	Supplied Reference
			the different suitable energy dissipator alternatives for the sewer outflow; in view of the exit Froude number, to minimize the wadi erosion.			
Essay # 2	**Sewerage Management, Treatment and Reuse**	WREE-T7-1	**Part (1)** A waste stabilization pond will be used in a municipal wastewater treatment system. (a) Explain the function of bacteria and algae in the stabilization ponds application. (b) Explain why algae would be a problem if it were present in the discharge from the pond. (c) Define mechanisms that could be utilized to control algae and that would prove helpful in the development and use of this wastewater treatment system. (d) Explain what is meant by facultative pond. **Part (2)** A secondary clarifier accepts effluent from a bioreactor at a flow rate of 8300 m^3/d and total suspended solids of 1600 mg/L. The solids flux for the suspension is 2.6 $kg/m^2.h$, and the particle settling velocity is 1.27 m/h. Determine the following: - 1. The solids loading rate 2. The required surface area based on solids flux 3. The required surface area based on particle settling velocity 4. The particle design surface area 5. The design overflow rate.	-	30 min	None

6. Solutions of Sample Questions

Multiple Choice Questions (MCQs)

Question # 1

WREE-T1: Fluid Mechanics, and Open Channel and Pipe Flow Hydraulics

WREE-T1-1 Apply theories and principles of hydrodynamics and flow equations; for example, mass, energy and momentum conservation principles, to solve water-related problems.

Estimate the time required to discharge runoff from a watershed that generates stormwater runoff volume of approximately 31,000 m3. Assume that the runoff will be discharged through a rectangular channel that is 1.20 m wide, 0.60 m deep and has a longitudinal slope of 0.2% and its Manning's roughness coefficient (n) is 0.022. If the channel flow is uniform at a depth of 0.45 m, then the time (hours) is nearest to:

A) 10
B) 16
C) 19
D) 23

Solution WREE-T1-1:

Applying Manning's equation:

A = b.y = 1.2 x 0.45 = 0.54 m2; P = b+2y = 1.2 + 2x0.45 = 2.1 m; R = A/P = 0.257 m

Q = 1/n [AR2/3 S1/2]

Q = 0.444 m3/s

Time = volume / Q = 31,000/0.444 s = 19.4 hr ~ 19 h

Answer WREE T1-1: (C)

Question # 2

WREE-T1: Fluid Mechanics, and Open Channel and Pipe Flow Hydraulics

WREE-T1-6 Design transmission pipelines and pipe networks; including selecting appropriate pumps and design of pump stations, where necessary.

A small village has a population of 6000 inhabitants. The daily water demand of the residents is estimated to be 150 l/c/d. A pump station is located near a river, such that the static head for all the pumps is 100 m. The pumps are to deliver river water to the village, and the available pumps from the closest dealer are 10-horsepower each with an efficiency (σ) of 70%. Assuming the head losses are 15% of the static head, the closest required number of pumps; given that they will be connected in parallel in the pump station and that their operating time is only 6 hours/day, would be:

A) 3
B) 5
C) 9
D) 12

Solution WREE-T1-6:

Q = 900 m3/d

This volume should be delivered within 6 hours; so, the discharge pumped would be:

Q = 900/6 = 150 m3/h or 0.0417 m3/s

Q_{pump} = 0.0417 / n; where n is the number of pumps

Applying the provided power formula and assuming the pumps are identical:

$h_p = h_{static} + h_{losses}$ = 100 x 1.15 = 115 m

$$p = \frac{\gamma Q h_p}{750 * \sigma}$$

10 = 9810 x (0.0417/n) x 115 / (750 x 0.7)

n = 8.9 pumps or ~ 9 pumps

Answer WREE T1-6: (C)

Question # 3

WREE-T2: Surface and Groundwater Hydrology

WREE-T2-10 Apply groundwater flow principles and assess groundwater quantity and quality.

Three groundwater wells; A, B, and C, are located such that the spacing between any two of them is 500 m. The following data are given for the wells:

Well Label	Ground El. (m)	Well Base El. (m)	Water Pressure Head at the Well Base (m)
A	150	50	32
B	120	38	45
C	175	50	27

The hydraulic gradient (i) for the flow potential between wells A and B is:

A) 0.002
B) 0.010
C) 0.012
D) 0.020

Solution WREE-T1-6:

By adding the provided water pressure head at the well base to the base elevation of wells A and B, the total energy elevation would be:

For well A: 82 m

For well B: 83 m

The flow potential would be from Well B to Well A, since Well B has higher energy level and the hydraulic gradient (i) would be:

i = (83-82)/500 = 0.002

Answer WREE T2-10: (A)

Question # 4

WREE-T3: Design of Hydraulic Structures

WREE-T3-5 Design erosion and sediment control structures; for example, stormwater ponds, dykes, spurs, guide banks, aprons, gabion baskets/mats, riprap ...etc.

An 18-inches circular culvert discharges 24 cfs onto a grassy embankment that has no defined channel. The minimum apron length, L_a, (ft) and minimum d_{50} (inches) of the required riprap at the culvert outlet to prevent erosion are closest to:

A) 13 ft, 8 inches
B) 20 ft, 9.6 inches
C) 22 ft, 12 inches
D) 25 ft, 15 inches

Solution WREE-T3-5:

Since the outflow discharges as overland flow onto grassy embankment with no defined channel, there will be no downstream control and the culvert would be inlet-controlled. Using the chart for TW < 0.5 d (page 39), the d_{50} is estimated at 0.8 ft or 9.6 inches and the L_a is approximately 18 ft. The closest answer to these values is (b).

Answer WREE T3-5: (B)

Question # 5

WREE-T2: Surface and Groundwater Hydrology

WREE-T2-8 Apply water budget principles to estimate potential water availability.

The six-month seasonal precipitation on a small watershed is 70 cm, the runoff is 20 cm, and the change in groundwater storage is 15 cm. What is the average monthly evapotranspiration rate (cm/month), assuming no initial abstraction?

A) 5.83
B) 20.24
C) 35.56
D) 65.23

Solution WREE-T2-8:

Applying the water budget equation assuming no initial abstraction:

$\Delta S = P - R - ET$; where ΔS is the change in groundwater storage, P is the precipitation, R is the runoff and ET is the evapotranspiration.

$15 = 70 - 20 - ET$

Therefore, ET = 35 cm/6 months or 5.83 cm/month on average.

Comment: This answer assumes no variability in the above parameters within the six-month season.

Answer WREE T2-8: (A)

Question # 6

WREE-T6: Water Treatment, Supply and Reuse

WREE-T6-9 Recognize performance metrics in water distribution systems.

What is the average monthly NRW (non-revenue water) in the case of a water company having an offtake agreement with a distribution company to supply into the system inlet reservoirs a daily quantity of 2,000,000 m3/day? This water is supplied 50% from underground aquifers using RO with an average reject rate of 65%. The distribution supply network has average commercial losses of 500,000 m3/day and physical losses of 700,000 m3/day. The monthly quantity of bills issued and collected by registered customers is equivalent to 45 million m3/month. So, the average monthly NRW is:

A) 25 %
B) 50 %
C) 75 %
D) 100 %

Solution WREE-T6-9:

In the case of the water company having an offtake from a distribution company to supply water, the efficiency of the water treatment plants is not of concern.

The revenue water over one month (30 days) is 2 million m3/day x 30 days/month = 60 million m3/month. The answer is (a), because the NRW is calculated based upon the difference from 100% in billing quantities against the total system input volume; i.e. 1 - 45/60 = 1 – 0.75 = 0.25 or 25%

Answer WREE T6-9: (A)

Question # 7

WREE-T7: Sewerage Management, Treatment and Reuse

WREE-T7-7 Apply sludge management/reuse practices.

An extended aeration tank, which is operated as continuous mixed reactor with length 50 meters, 20 meters wide and a hydraulic level of 4 meters deep, requires a sludge age of 10 days to achieve a MLSS of 2,500 mg/l. What is total volume of sludge (in m^3) withdrawn per day, if the average daily feed is 1,000 m^3/day?

A) 200
B) 400
C) 8,000
D) 1,000

Solution WREE-T7-7:

The answer is b; it is calculated simply as 1/10th of the volume of the aeration volume.

Answer WREE T7-7: (B)

Question # 8

WREE-T9: Air Quality Management

WREE-T9-1 Define air pollution and air quality indices.

Does the impact of higher ambient air temperature on the air quality increase or decrease the Yale Environmental Pollution Index?

A) Higher temperature increases the Yale Environmental Pollution Index because of higher rate of evaporation of any hazardous volatile components in the air
B) Higher temperature decreases the Yale Environmental Pollution Index because of the higher rate of evaporation of any hazardous volatile components in the air
C) There is no change to the Yale Environmental Pollution Index because the calculation factors in variance in ambient air temperature
D) Not possible to answer because it would depend on the type of air quality contaminants and knowledge of meteorological data such as humidity, and windrose data

Solution WREE-T9-1:

The answer to this question requires an understanding of both air quality impacts on temperature and background information on the Yale Environmental Pollution Index. The answer is that although air pollution increases generally with high temperatures because of increase in ground level ozone that will cause further oxidation of nitrogen dioxide, that it is not possible to state specifically regard to the Yale Environmental Pollution Index because an overall understanding of the exact type of pollutants and meteorological conditions.

In Saudi Arabia because of the vast differences in regions and localities there are areas for example of industrial cities near the coast where the Yale Environmental Pollution Index would be affected by the presence of the humidity changes from the coastline as well as wind characteristics. This would be different for example in calculating the Yale Environmental Pollution Index for industrial areas located inland.

The correct answer is therefore d.

Answer WREE T9-1: (D)

Question # 9

WREE-T9: Air Quality Management

WREE-T9-3 Design air quality monitoring and treatment systems.

What is the best description from the list below that describe the BPEO / BATNEEC principles for Flue Gas Desulphurisation System (FGD)?

A) Fluidized Incineration / wet air oxidation
B) Radiation technology
C) Limestone forced oxidation
D) Physical chemical scrubber separation

Solution WREE-T9-3:

This question also requires knowing what the definition of BPEO is and BATNEEC – these are defined respectively as best practical environmental option and best available technique not entailing excessive cost respectively.

FGD systems work with a variety of reagents, such as limestone, magnesium-enriched lime, and waste soda ash or limestone-based systems using organic acid enhancement

As traditional best practice, the FGD either work as wet scrubbing systems in which the flue gas normally passes first through a fly ash removal device, either an electrostatic precipitator or a baghouse, and then into the SO 2-absorber; or through a dry injection or spray drying operations, where the SO2 is first reacted with the lime, and then the flue gas passes through a particulate control device.

The concept of BPEO/ BATNEEC comes into consideration is the knowing that scrubbing is the most tried and robust solution , although there are certain mitigation measures associated with ensuring the durability of the treatment technology and using techniques, such as reheating the gases to above their dew point, or using materials of construction and designs that allow equipment to withstand the corrosive conditions . Technology such as fluidized incineration or wet air oxidation is not prone to corrosivity issues from the gases as the gases are incinerated; however, this technology is not proven and is expensive and does not represent BPEO/BATNEEC. The other answers b and c are not proven – hence the correct answer is d.

Answer WREE T9-3: (D)

Question # 10

WREE-T11: Environmental Risk and Performance Management Modeling

WREE-T11-2 Identify and quantify environmental risks and liabilities.

What are the main risks in designing a co-compost facility to treat domestic and sewage wastes?

A) Domestic waste generally has a low percentage (less than 30 % of organic biodegradable wastes)
B) There is a need to have an initial good performance from a materials recycling facility to separate the domestic wastes (organic from non-organic wastes)
C) There is need to have a good pretreatment and monitoring of all wastes prior to co-composting
D) The risk will not be meeting the Ministry of Agriculture, Water and Environmental standards for reuse of composting for agricultural land use

Solution WREE-T11-2:

This question requires an understanding of what are risks in designing environmental technology. The technology must be designed to meet the standards and in this case for a composting plant in Saudi Arabia, it would be to the Ministry of Agriculture, Water and Environmental Standards if the compost is to be used for irrigation. If, however the plant is intended to generate fertilizer components, such as perlite, for industrial use then it would be according to the industrial / commercial requirements. However, considering the standard is not a risk – it is a treatment objective.

The risk is the need to have appropriate pre-treatment to ensure the domestic waste being sent to treatment contains only the organic fraction (typically it would be around 55 %). If it is lower than this or the feed contains items such as metals which cannot be composted, then the risk would be that the inlet requirements to the plant would not meet the requirements of a minimum organic contents for biodegradation or conversion through the methagonic digestion process to provide compost or compost elements. For the sewage waste it would be to ensure there is no heavy metals and the dryness and odour does not present a risk to the design of the compost plant.

Hence, the correct answer is c.

Answer WREE T11-2: (C)

Essay Questions

Essay Question # 1

WREE-T3: Design of Hydraulic Structures

WREE-T11-2 Design outfall structures; including energy dissipaters.

A 1200-mm diameter concrete end sewer discharges the storm runoff from a small town into a narrow wadi edging the town. The sewer is designed to convey the 100-year storm discharge estimated at 6 m^3/s while flowing 1/2 full. Discuss the suitability of the sewer material and any necessary requirements to ensure its durability if the material can not be changed. Also, describe the different suitable energy dissipator alternatives for the sewer outflow; in view of the exit Froude number, to minimize the wadi erosion.

Write an essay that answers the above requirements.

Answer to Essay Question number 1

Preliminary calculations:

Diameter, d = 1.2 m

Area of flow, $A = ½ (\pi d^2/4) = ½ (3.14 \times 1.2^2/4) = 0.565\ m^2$

Average flow velocity, v = Q / A = 6/0.565 = 10.61 m/s

Hydraulic radius, R = A/P; where P = π d/2 = 1.88 m, hence R = 0.3 m

Froude no. $= \frac{v}{\sqrt{gR}} = 6.19$

Based on the provided information of discharge, sewer diameter and flow depth, the estimated average flow velocity would be 10.61 m/s. This is relatively a high velocity that may result in erosion of concrete over the long term. It is ideal if the sewer material is replaced by a PVC pipe, for example. However, if only concrete pipes are available then additives; such as fly ash, or reduced water/cement ratio of the concrete will be required to increase the erosive resistance of the concrete.

At such high velocity, Froude number of the outfall would be approximately 6.19. This indicates that the outflow is super-critical. To minimize the erosive power of the outflow on the receiving wadi bed, different measures may be taken depending on the site conditions and the available limits of disturbances. One of the measures could be to install a manhole or a catch basin manhole on the downstream side of the sewer line; such that another end-sewer at a milder slope would covey the flow to a stilling basin with baffle blocks and possibly end sill to reduce the flow velocity and convert the flow state to sub-critical conditions.

Another means to dissipate the energy of the outflow is to design one of the known USBR basins at the end of the sewer. At such high value of Froude number, the USBR Impact Basin with baffle wall may be an appropriate choice.

It may also be possible to design a rock chute with appropriate riprap or gabion baskets configuration that would reduce the erosive power of the outflow and result in its safe discharge to the wadi.

The above alternatives should be investigated based on cost and availability, as well as the urgency and time of construction before a decision is made.

Essay Question # 2

WREE-T7: Sewerage Management, Treatment and Reuse

WREE-T7-1 Design different types of municipal wastewater treatment plants.

Part (1)

A waste stabilization pond will be used in a municipal wastewater treatment system.

A) Explain the function of bacteria and algae in the stabilization ponds application.
B) Explain why algae would be a problem if it were present in the discharge from the pond.
C) Define mechanisms that could be utilized to control algae and that would prove helpful in the development and use of this wastewater treatment system.
D) Explain what is meant by facultative pond.

Solution

(a) A waste stabilization ponds operation is dependent on the reaction of bacteria and algae. Organic matter is metabolized by bacteria to produce the principle products of carbon dioxide, water and a small amount of ammonia nitrogen. Algae convert sunlight into energy through photosynthesis. They utilize the end products of cell synthesis and other nutrients to synthesize new cells and produce oxygen. The most important role of the algae is in the production of oxygen in the pond for use by aerobic bacteria. In the absence of sunlight, the algae will consume oxygen in the same manner as bacteria. Algae removal is important in producing a high-quality effluent from the pond.
(b) The discharge of algae increases suspended solids in the discharge and may present a problem in meeting water quality criteria. The algae exert, an oxygen demand when they settle to the bottom of the stream and undergo respiration.
(c) The following methods have been suggested for control of algae: (1) multiple ponds in series, (2) drawing off of effluent from below the surface by use of a good baffling arrangement to avoid algae concentrations, (3) sand filter or rock filter for algae removal, (4) alum addition and flocculation, (5) micro-screening, and (6) chlorination to kill algae. Chlorination may increase BOD loading due to dead algae cells releasing stored organic material.
(d) Facultative ponds have two zones of treatment: an aerobic surface layer in which oxygen is used by aerobic bacteria for waste stabilization and an anaerobic bottom zone in which sludge decomposition occurs. No artificially induced aeration is used.

Part (2)

A secondary clarifier accepts effluent from a bioreactor at a flow rate of 8300 m^3/d and total suspended solids of 1600 mg/L. The solids flux for the suspension is 2.6 kg/m^2.h, and the particle settling velocity is 1.27 m/h. Determine the following: -

1. The solids loading rate

2. The required surface area based on solids flux

3. The required surface area based on particle settling velocity

4. The particle design surface area

5. The design overflow rate

Solution

1. The solids loading rate is

= (1600 mg/L) (8300 m^3/d) (10^{-6} kg/mg) (1000 L/m^3)

= 13 280 kg/d

2. As = surface area teased on solids flux, m^2

Q = flow rate =8300 m^3/d

X = influent TSS = 1600 mg/L

G = solids flux = 2.6 kg/m^2.h

$$\text{As} = \frac{\text{Q X}}{\text{G}} = \frac{\left(8300\frac{\text{m3}}{\text{d}}\right)\left(1600\frac{mg}{L}\right)\left(10-6\frac{kg}{mg}\right)(1000\ L/m3)}{\left(2.6\frac{\text{kg}}{\text{m2}}.\text{d}\right)\left(\frac{24h}{d}\right)}$$

= 213 m^2

3. As = surface area teased on settling velocity, m2

$$= \frac{(8300\frac{\text{m3}}{\text{d}})}{\left(1.27\frac{\text{m}}{\text{h}}\right)\left(\frac{24\text{h}}{\text{d}}\right)} = 272 \text{ m2}$$

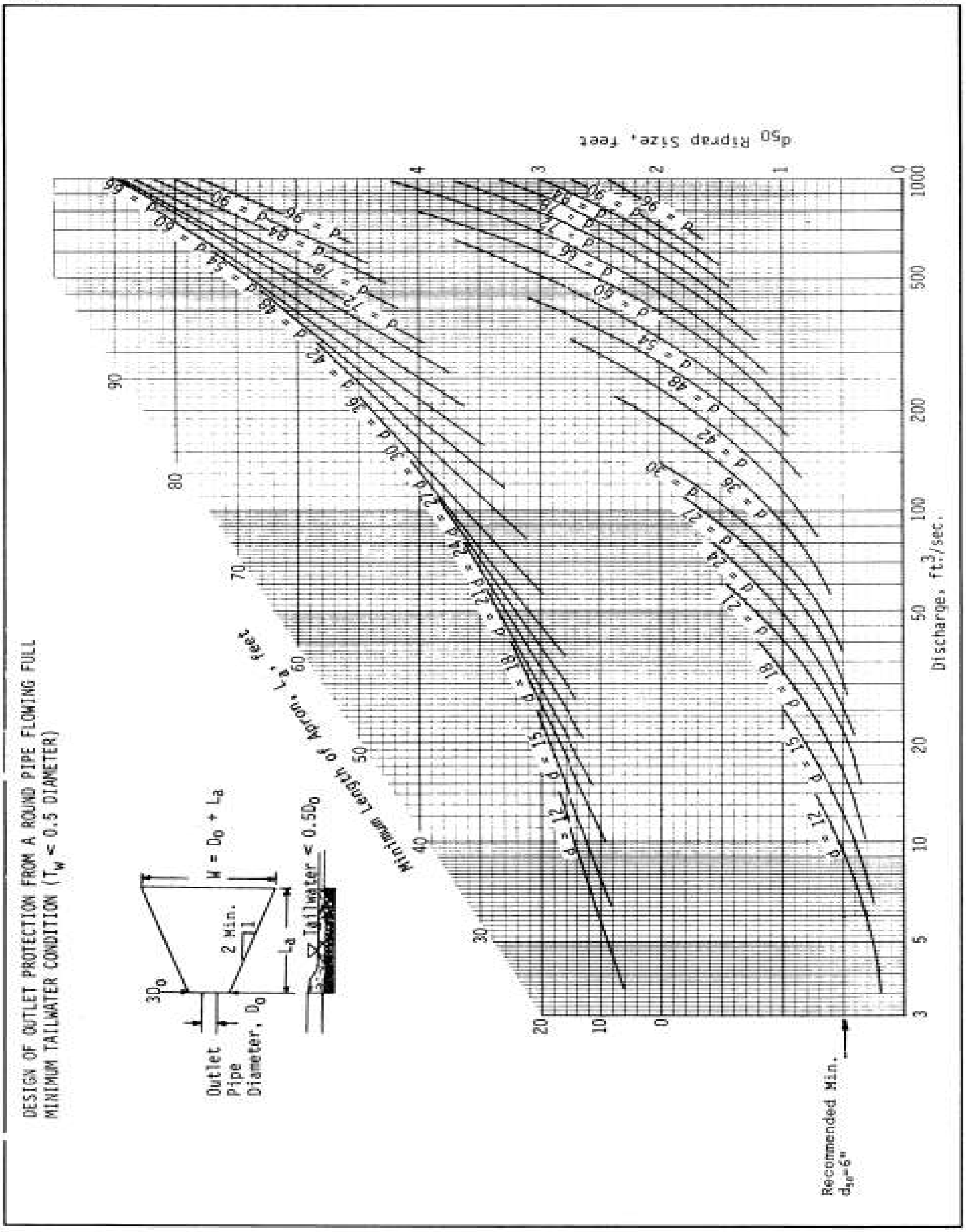
4. The design surface area is the greater of the areas based on solids flux and settling velocity. The Settling velocity area of 272 m2 is greater than the solids flux area of 213 m^2. Then the design area is 272 m^2.

5. The design overflow rate $$q = \frac{\text{Q}}{\text{AS}} = \frac{(8300\frac{\text{m3}}{\text{d}})}{(\text{ 272 m2})(24\frac{h}{d})}$$

= 1.27 m^3/m^2.h

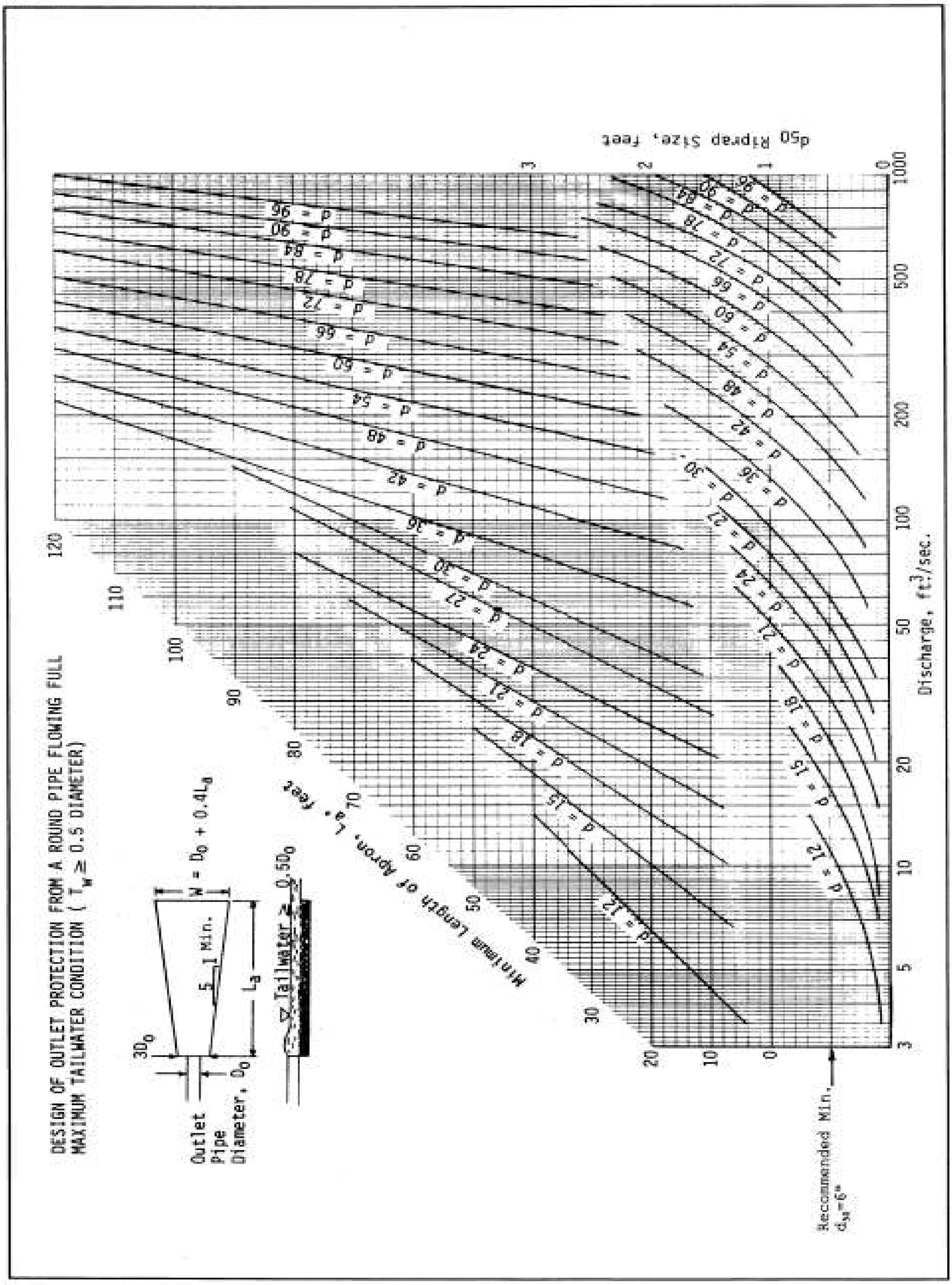
Design Charts

1992 3.18



Source: USDA-SCS Plate 3.18-3

1992 3.18



Source: USDA-SCS

Plate 3.18-4

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