TULE WIND PROJECT

STORM WATER MANAGEMENT PLAN

DRAFT

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TABLES

FIGURES

APPENDICES

EXECUTIVE SUMMARY

The purpose of this Storm Water Management Plan (SWMP) is to identify potential impacts to water quality from development of the Tule Wind Project (Project) and to investigate Best Management Practices (BMPs). This report is intended to accompany and support the Environmental Impact Statement (EIS)/Environmental Impact Report (EIR) in accordance with the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA). The following regulations and guidelines apply to the water quality for the Project:

- Clean Water Act of 1977 Section 311 and 402, United States Code Title 33 Section 1342, Code of Federal Regulations Title 40 Parts 123-136;
- California Porter-Cologne Water Quality Control Act 1998, California Water Code Section 13000-14957, Division 7;
- California State Water Resources Control Board National Pollutant Discharge Elimination System (NPDES) General Permit for Storm Water Discharges Associated With Construction and Land Disturbance Activities, Order No. 2009-0009-DWQ (General Construction Permit);
- San Diego County Standard Urban Storm Water Mitigation Plan (SUSMP), March 2008,
- County of San Diego Watershed Protection, Storm Water Management and Discharge Control Ordinance (County Ordinance 9589),
- County of San Diego Stormwater Standards Manual,
- California Regional Water Quality Control Board San Diego Region Order No. R9-2007-0001, NPDES No. CAS0108758.
- Colorado River Basin Region 7 Water Quality Control Plan, California Regional Water Quality Control Board.
- California Stormwater Quality Association Stormwater Best Management Practice Handbooks.

All portions of the Project are within the County of San Diego with portions outside of existing Phase I and Phase II Region 9 State Water Resources Control Board NPDES permits. No Phase I or Phase II project areas are within County of San Diego jurisdiction, rather they are on Federal or Indian Reservation land. This being the case, the Project is required to address the California State Water Resources Control Board NPDES General Construction Permit post-construction BMP guidelines. However, since the Project is located within San Diego County, the County of San Diego SUSMP guidelines and the General Construction Permit post-construction BMPs are considered for all project areas. Based on these governing documents the following items are included in the SWMP:

Project description and vicinity map,

Site map defining drainage patterns, existing storm drain systems, proposed drainage crossings, soil types, existing land types, and existing and proposed slopes,

Identification of Pollutants of Concern,

Identification of Conditions of Concern,

Identification of Site Design BMP recommendations, Preliminary hydromodification discussion,

Identification of Source Control BMPs,

BMPs for Individual Priority Project Categories,

Identification of Treatment Control BMP recommendations, and

Storm Water BMP maintenance discussion.

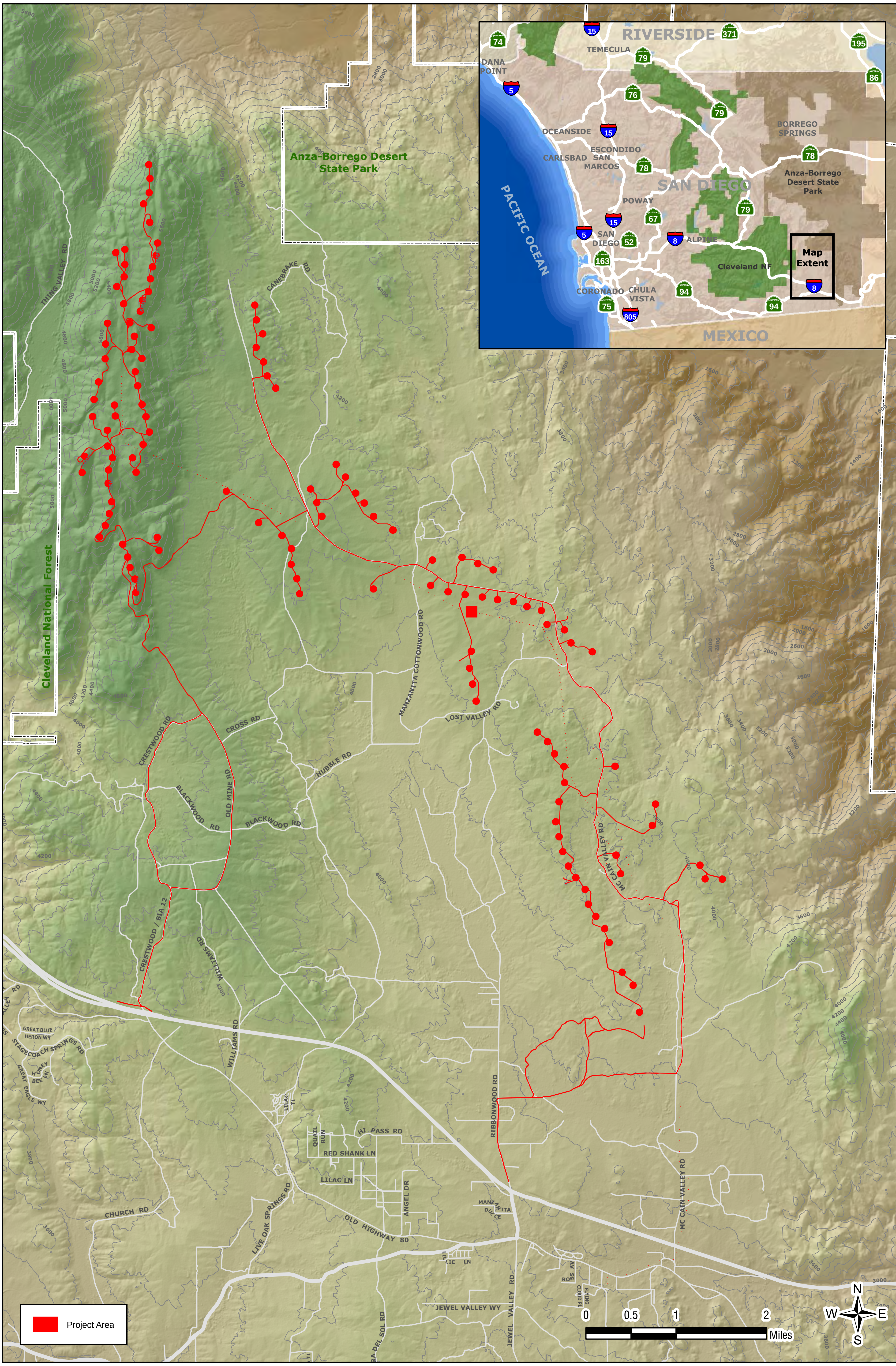
1.0 PROJECT DESCRIPTION

The Tule Wind Project proposes to develop a wind turbine "farm" for power generation, in the County of San Diego in the State of California. The project area is located in the eastern portion of San Diego County, approximately 50 miles east of City of San Diego, 90 miles west of Arizona, and north of the community of Boulevard (see Figure 1). The area is accessible via Interstate 8 (I-8), State Route 94 (SR-94) and Ribbonwood Road junction, and McCain Valley Road off of Old Highway 80. The majority of the project area lies in the In-Ko-Pah Mountains adjacent to the Tecate Divide, south of the Cleveland National Forest. The topography of the area is gently-to-steep sloping with an elevation ranging between about 3,600 and 5,600 feet above mean sea level. The project area contains lands administered by the BLM, the Ewiiaapaayp Reservation, the Campo and Manzanita Reservations (access only), the California State Lands Commission (CSLC), and privately-owned parcels under the jurisdiction of the County of San Diego. Permanent Project impact areas investigated for water quality are approximately 513-acres, which conservatively assumes development of all siting alternatives.

Under existing conditions the Project site is mainly undeveloped naturally vegetated rocky hills. A number of existing access roads traverse the area, providing service routes to existing utility facilities, commercial facilities, rural houses, agricultural facilities, and a landing strip. Existing topography is fairly steep with some flatter drainage courses at the base of the some of the hills and gullies. Naturally occurring native vegetation is predominant throughout the site, with periodic scattered unvegetated rock outcroppings.

Development will consist of up to 128 wind turbines, 34.5 kilovolt (kV) overhead and underground collector lines, 138 kV overhead transmission line, 5-acre collector substation site, 5-acre operation and maintenance building site, access road between turbines, improvements to existing roads to provide site access, 5-acre temporary batch plant, 10-acre temporary parking lot, 19 2-acre lay down areas, two meteorological towers, and a sonic detection and ranging system (SODAR) unit. Figure 2 illustrates the site configuration.

Proposed wind turbines range in size between 328 feet in height to 492 feet in height, to produce 200 megawatts total power. Turbines are constructed with a 48-foot diameter concrete foundation. Concrete foundations slope away from the centrally located turbine and will be buried greater than half a foot, so that exposed concrete foundations are approximately 6-inches to 8-inches thick and 18-feet to 20-feet in diameter. Turbines also include five-foot by nine-foot concrete pads for transformer foundations. Graded dirt pads around the turbines will be approximately 200-feet radius.



Region and Vicinity

FIGURE 1

Tule, LLC | Tule Wind Project

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Access roads between turbines will be 36-feet wide to accommodate self propelled cranes and supply trucks, while access roads to the turbine strings will only need to be 24-feet wide, as the crane and other assembly equipment can be brought onsite in pieces. Thirty-six foot access roads between turbines are intended to be temporary for construction activities and will be allowed to revegetate to a 20-foot width, pending construction completion. Roads under San Diego County jurisdiction will revegetate to a 24-foot width to comply with County standards. Proposed access road alignments will follow existing access roads to the maximum extent practicable to limit the amount of additional disturbed areas. New access roads will follow existing contours to maximum extent practicable to limit the amount of disturbed areas resulting from grading cuts.

Operation and maintenance facility pads and substation pads will be graded to allow for construction of the required facilities and the accompanying access and operation spaces. Impervious areas associated with these facilities will be minimal, limited to the structures themselves. All access and parking areas will be constructed of permeable materials. Additionally, there is the potential for detention basins attached to these graded pads, in order to adequately address water quality concerns.

Electrical collector lines for the Project will be a combination of overhead and buried, with a majority being buried. Overhead collector lines will be supported by single steel or wood poles; typically 60-feet to 80-feet in height. Foundation footprints for collector line poles will be similar to the diameter of the pole itself. Collector line temporary disturbed widths are assumed to be 24-feet to allow construction vehicle access and trenching or pole erection. Transmission lines will be carried by approximately 75-foot tall poles spaced 600-feet to 700-feet. Temporary transmission line disturbed areas are assumed to be 24-feet to allow construction vehicle access and pole erection. After construction natural vegetation will be established over collector line and transmission line access roads. All buried collector lines will be completely re-vegetated.

Temporary parking lot, batch plant, and lay down areas will be re-vegetated to existing conditions and are not deemed a permanent impact. In addition, all naturally occurring vegetation around proposed grading and facilities will be returned to a naturally vegetated state upon completion of construction activities.

Project development will increase impervious areas by a very small amount. Each turbine pad represents approximately 360 square feet of impermeable area in addition to the impervious building footprints at the operation and maintenance pads and substation pads. Overall Project development proposes to increase impervious area by approximately 55,000 square feet or 0.3% for the overall 513 acre site.

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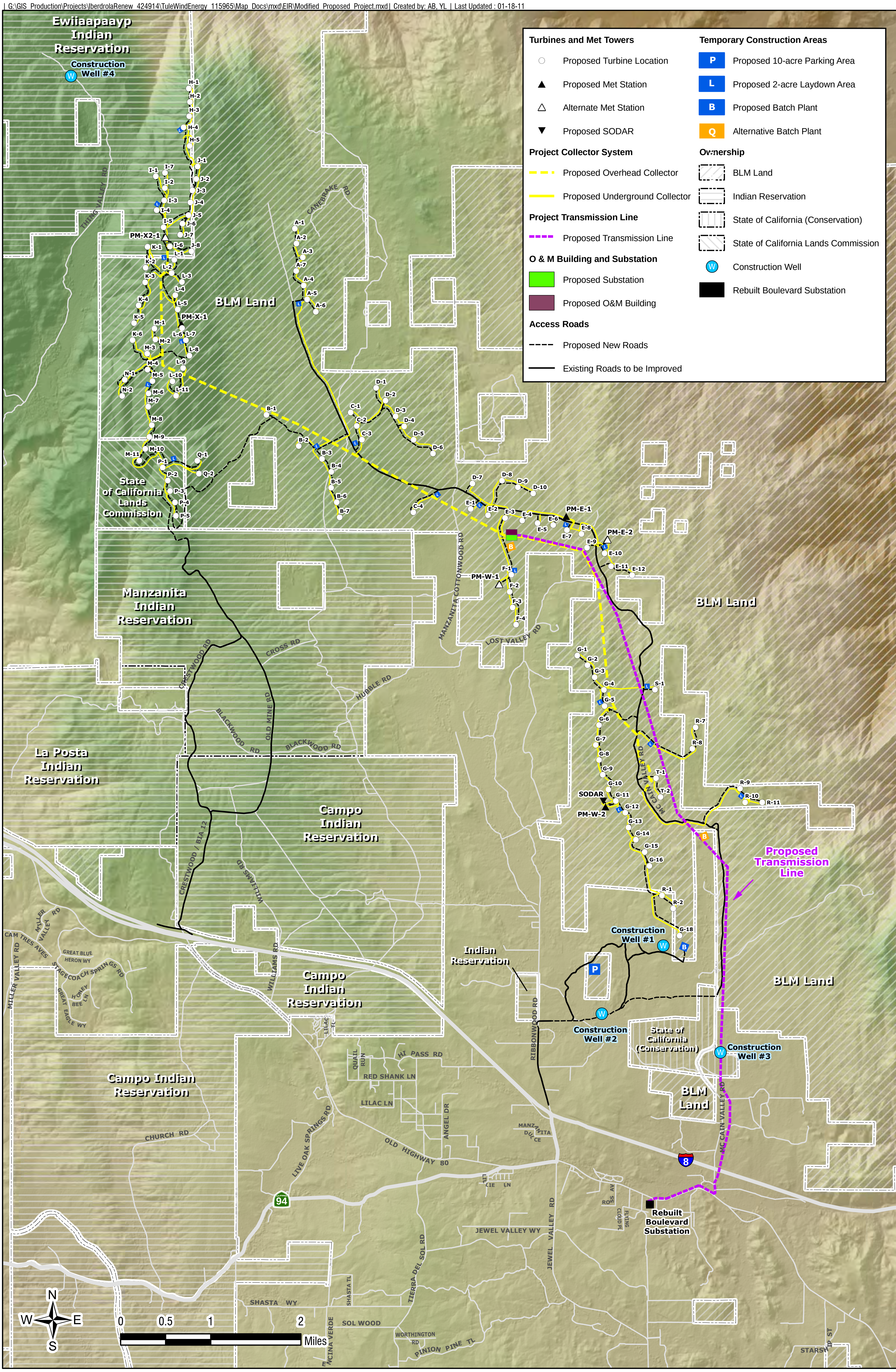

Project Layout

FIGURE 2

Tule Wind, LLC | Tule Wind Project

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1.1 PROJECT REQUIREMENTS

Using the County of San Diego SWMP approach as a guideline in conjunction with General Construction Permit requirements, Project water quality mitigation criteria were established. Based on the County of San Diego SUSMP, a Stormwater Intake Form for Development Projects was completed for the Project and is included in Appendix B. Based on the checklist, the Tule Wind Project is considered a priority project and is required to adhere to Major SWMP requirements. A completed Major SWMP form is included in the SWMP for private County of San Diego Project areas, published by HDR under a separate cover. Priority project criteria are outlined in the SUSMP Standard Storm Water BMP Selection Matrix as shown in Table 1. General Construction Permit post-construction BMPs are required for all projects outside of Phase I and Phase II projects, and include site design considerations, source control considerations and treatment alternatives. Based on this, Project development will require site design, source control, priority project BMPs, and treatment control BMPs, to be discussed in Sections 4, 5, 6, and 7, respectively.

Table 1: Standard Storm Water BMP Selection Matrix

Priority Project Category	**Site Design BMPs(1)**	**Source Control BMPs(2)**	**Requirements Applicable to Individual Priority Project Categories(3)**										
			a. Private Roads	b. Residential Driveways & Guest Parking	c. Dock Areas	d. Maintenance Bays	e. Vehicle Wash Areas	f. Outdoor Processing Areas	g. Equipment Wash Areas	h. Outdoor Processing Areas	i. Surface Parking Areas	j. Fueling Areas	k. Hillside Landscaping
Detached Residential Development	R	R	R	R									R
Attached Residential Development	R	R	R	R									R
Commercial Development >1 Acre	R	R			R	R	R	R					
Heavy industry/industrial development	**R**	**R**	**R**		**R**	**R**	**R**	**R**	**R**			**R**	
Automotive Repair Shop	R	R			R	R	R		R	R		R	
Restaurants	R	R			R				R				
Hillside Development >5,000 ft^2	**R**	**R**	**R**										**R**
Parking Lots	R	R								R(4)			
Retail Gasoline Outlets	R	R				R	R					R	
Streets, Highways & Freeways	R	R									R		

R=Required; select one or more applicable and appropriate BMPs from the applicable steps in section 4.1 &4.2, or equivalent as identified in section 4.6.1-4.6.3.
(1) Refer to Section 4.1.
(2) Refer to Section 4.2.
(3) Priority project categories must apply specific stormwater BMP requirements, where applicable. Projects are subject to the requirements of all priority project categories that apply.
(4) Applies to the paved area totals >5,000 square feet or with >15 parking spaces and is potentially exposed to urban runoff.

2.0 POLLUTANTS OF CONCERN

Under existing conditions pollutants generated by the Project site include sediments, nutrients, trash & debris, oil & grease, bacteria & viruses, and pesticides. Based on the County of San Diego SUSMP anticipated pollutants for hillside developments and industrial developments are sediment, nutrients, heavy metals, organic compounds, oil & grease, trash and debris, oxygen demanding substances, and pesticides. Table 2 outlines the pollutants of concern as shown in the County of San Diego SUSMP. However, based on the minimal amount of development that is proposed, anticipated pollutants are more likely to be sediment from dirt roads and turbine pads, and oil and grease from the vehicles using roads.

Table 2: Anticipated and Potential Pollutants Generated by Land Use Type.

	General Pollutant Categories								
Priority Project Categories	**Sediments**	**Nutrients**	**Heavy Metals**	**Organic Compounds**	**Trash & Debris**	**Oxygen Demanding Substances**	**Oil & Grease**	**Bacteria & Viruses**	**Pesticides**
Detached Residential Development	X	X			X	X	X	X	X
Attached Residential Development	X	X			X	P(1)	P(2)	P(1)	X
Commercial Development >1 Acre	P(1)	P(1)		P(2)	X	P(5)	X	P(3)	P(5)
Heavy industry/industrial development	**X**		**X**	**X**	**X**	**X**	**X**		
Automotive Repair Shop			X	X(4)(5)	X		X		
Restaurants					X	X	X	X	
Hillside Development >5,000 ft^2	**X**	**X**			**X**	**X**	**X**		**X**
Parking Lots	P(1)	P(1)	X		X	P(1)	X		P(1)
Retail Gasoline Outlets			X	X	X	X	X		
Streets, Highways & Freeways	X	P(1)	X	X(4)	X	P(5)	X		

X = anticipated
P = potential
(1) A potential pollutant if landscaping exists on-site.
(2) A potential pollutant if the project includes uncovered parking areas.
(3) A potential pollutant if land use involves food or animal waste products.
(4) Including petroleum hydrocarbons.
(5) Including solvents.

2.1 RECEIVING WATERS

A number of existing streams will convey flows generated by the Project. A majority of the Project drains to the east ultimately discharging into the Salton Sea. Approximately one sixth of the Project drains runoff to the west, ultimately discharging into the Pacific Ocean at the Tijuana Estuary.

A northeastern ridgeline crosses the easterly draining portions of the Project, dividing Salton Sea bound flows southwest into Tule Creek and northeast into Carrizo Wash, Bow Willow Creek, and Canebrake Wash. Approximately one third of the Project drains to Tule Creek via McCain Valley and Lark Canyon. Tule Creek flows are conveyed southeast into Tule Lake, which discharges into Tule Canyon, then converges with Carrizo Wash in Carrizo Gorge. Tule Creek and Bow Willow Creek are natural unconfined streams. A small portion of the Project along the southeast, in close proximity to Interstate 8 (I-8), is conveyed into Walker Creek on the south side of I-8. Walker Creek conveys flows into Carrizo Wash. After picking up Walker Creek and Tule Creek, Carrizo wash flows northeasterly where it picks up discharges from Bow Willow Creek and Vallecito Creek. Vallecito Creek is a natural stream. Vallecito Creek conveys flows from Canebrake Wash into Carrizo Wash. All flows in Carrizo Wash are then conveyed into San Felipe Creek and the Salton Sea. The Salton Sea is a minimum of approximately 45 miles downstream of the Project.

Westerly draining flows (Simmons Canyon, Unnamed Western Wash, and Basin No. 300 - 1000) are conveyed into La Posta Creek, which conveys flows into Cottonwood Creek, discharging into Lake Morena. The dam at Lake Morena discharges back into Cottonwood Creek, which then discharges into Barrett Lake. Barrett Lake dam releases flows back into Cottonwood Creek, which discharges into the Tijuana River and into the Pacific Ocean. Cottonwood creek is a natural unconfined stream. Lake Morena is a minimum of approximately 14 miles downstream of the Project. Table 3 contains a summary of drainages receiving runoff directly from Project areas and drainages indirectly receiving runoff from Project areas.

Southerly draining flow (Basin No. 1100) is conveyed into Miller Creek, which conveys flows into Campo Creek, which then conveys into Tijuana River and into the Pacific Ocean. The hydrologic unit is 911.83. Both the Miller Creek and Campo Creek are natural streams.

Based on the Project location and the existing conditions, there are no dry weather flows for drainages associated with this Project. There are minimal existing rural developments within the Project drainage basins that would generate flows during dry weather. Frequent site visits during the dry season confirmed that no flows were present in drainages associated with the Project.

Easterly draining Project areas are located in three hydrologic sub-areas, McCain, Carrizo, and Canebrake; hydrologic units 722.71, 722.61, and 722.63, respectively. These easterly draining sub-areas are conveyed through Ocotillo Lower Felipe hydrologic sub area; hydrologic unit 722.20. Westerly draining Project areas are located in the Cameron (Basin No. 100, 200) hydrologic sub-area; hydrologic unit 911.70. Cameron sub-area drains through the Cottonwood, Morena, Barrett Lake, Barrett, Marron, Water Tanks, and San Ysidro hydrologic sub-areas before reaching the Pacific Ocean; hydrologic units 911.60, 911.50, 911.30, 911.23, 911.21, 911.12, 911.11, respectively.

Table 3: Project Drainages and Hydrologic Unit Summary.

Drainage Name	Ultimate Discharge	Watershed	Hydrologic Area	Hydrologic Sub-Area	Hydrologic Unit
Direct Project Drainages					
Tule Creek	Carrizo Creek	Anza Borrego	Jacumba	McCain	722.71
Walker Creek	Carrizo Creek	Anza Borrego	Jacumba	McCain	722.71
Canebrake Wash	Carrizo Creek	Anza Borrego	Agua Caliente	Canebrake	722.63
Bow Willow Creek	Carrizo Creek	Anza Borrego	Agua Caliente	Carrizo	722.61
Carrizo Creek	San Felipe Creek	Anza Borrego	Agua Caliente	Carrizo	722.61
La Posta Creek	Cottonwood Creek	Tijuana	Cameron	Cameron	911.70
Miller Creek	Campo Creek	Tijuana	Campo	Clover Flat	911.83
Indirect Downstream Project Drainages					
San Felipe Creek	Salton Sea	Anza Borrego	Ocotillo Lower Felipe	Ocotillo Lower Felipe	722.20
Cottonwood Creek	Tijuana River	Tijuana	Cottonwood, Morena, Barrett Lake, Potrero	Cottonwood, Morena, Barrett Lake, Barrett	911.60, 911.50, 911.30, 911.23
Tijuana River	Pacific Ocean	Tijuana	Potrero, Tijuana Valley	Marron, Water Tanks, San Ysidro	911.21, 911.12, 911.11

2.1.1 303 (d) List of Water Bodies and Pollutants of Concern

Based on the 303(d) list approved by the United States Environmental Protection Agency (USEPA) in 2006, the Salton Sea is listed for nutrients, salinity, and selenium. Salton Sea pollutant sources are identified as agricultural, major industrial, point source, or out of state. Morena Reservoir and Barrett Lake are listed for color, manganese, and pH; with pollutant sources unknown. The Tijuana River is listed for eutrophic, indicator bacteria, low dissolved oxygen, pesticides, solids, synthetic organics, trace elements, and trash. Tijuana River pollutant sources are listed as nonpoint and point source. The Tijuana Estuary is listed for eutrophic, indicator bacteria, lead, low dissolved oxygen, nickel, pesticides, thallium, trash, and turbidity. Tijuana Estuary pollutant sources are listed as nonpoint, point source, urban runoff, wastewater, and unknown sources. Based on the distance of impaired water bodies from the Project Site and the opportunity for natural pollutant removal in conveyance features, only Morena Reservoir could be impacted by Project development.

Currently there are no Region 9 State Water Resources Control Board (SWRCB) special requirements for any water bodies that will be impacted by this Project. Based on the available information there are no High Risk Areas within the Project limits.

Comparison of the anticipated pollutants and the receiving water bodies' impairments indicates there are no primary pollutants of concern. Secondary pollutants of concern are sediment and oil and grease.

3.0 CONDITIONS OF CONCERN

A Preliminary EIS/EIR Drainage Report dated September 2010 was completed by HDR under a separate cover and discusses the existing and proposed drainage patterns for the Project. A review of this drainage summary is presented below.

3.1 EXISTING DRAINAGE PATTERNS

Project areas are drained by 19 drainage basins. Overall runoff patterns are either westerly to the Pacific Ocean or easterly to the Salton Sea. Westerly draining basins include Simmons Canyon, Western Unnamed Wash, and Basins 300-1100. Easterly draining basins include Tule Creek, Bow Willow Creek North, Bow Willow Creek South, Northern Unnamed Wash, Eastern Unnamed Wash, and Basins 100-200, 1200, and 1300. Table 4 presents a summary of the drainage basins and areas.

Table 4: Drainage Basin Summary

Watershed	Basin Area (acres)
Tule Creek	18,250
Bow Willow Creek North	2,747
Bow Willow Creek South	5,197
Northern Unnamed Wash	1,542
Eastern Unnamed Wash	734
Western Unnamed Wash	1,440
Simmons Canyon	878
100	86
200	376
300	242
400	73
500	192
600	165
700	122
800	475
900	189
1000	102
1100	636
1200	486
1300	71
Total	**34,001**

All basins have similar drainage patterns. Runoff sheet flows across the ground surface until it encounters rivulets which then discharge into larger streams which ultimately discharge easterly or westerly. Precipitation that falls on typical existing access roads sheet flows off the side of the roads where it is either collected in swales running parallel to the road or continues to sheet flow across the natural terrain. Swales carry runoff to streams crossing the access road, where they are then conveyed to major drainage features.

There are no major improvements to the drainage features within the basins. However, a number of culverts have been installed on portions of several of the basins to facilitate access roads across the smaller drainage features. An unnamed tributary to Tule Creek along the northeastern edge of the Project crosses a number of public and private roads via culverts just east of the landing strip. A number access roads scattered throughout the drainage basins utilize a depressed on grade type crossing, where flows are conveyed across the top of the road, rather than constructing culverts to carry flows under the road (Arizona crossing). Ribbonwood road crosses a number of drainage features along the southwestern portion of the Project utilizing both culverts and Arizona type low flow crossings. Tule Creek crosses a number of existing access roads via culverts or Arizona type low flow crossings. Exhibit A presents the existing drainage patterns. Detailed drainage patterns can also be found in the HDR Preliminary Drainage Report (published under a separate cover).

3.2 PROPOSED DRAINAGE PATTERNS

Proposed Project improvements will mimic existing drainage patterns and will minimize redirection of any flows. Improvements include graded pads, access roads, and utility lines, and constructed crossings at each drainage feature.

All proposed project crossings of existing drainage features will utilize a stabilized Arizona type crossing. Arizona crossings will be constructed similar to San Diego County Design Standard DS-14 without low flow culverts. Road surfaces will be stabilized with articulated concrete block (ACB) systems or reinforced concrete, or equivalent, depending on crossing flow rates. Riprap protection, or equivalent, will be provided in the channel immediately upstream and downstream of the crossing to protect against soil erosion and increased sediment loads.

Precipitation falling on graded pads will sheet flow off the proposed features and finished surfaces to swales/brow ditches that will collect runoff. Runoff from the exposed portions of the turbine pads will flow through a layer of placed gravel. Runoff will then be directed to the existing natural surface drainage features, with flow patterns intended to mimic existing conditions.

Proposed electrical collector lines will be located throughout the Project. Minor effects on drainage patterns from collector lines or transmission lines may occur during construction. Once the collector and transmission lines are either hung or buried the surrounding vegetation and grades will be restored to existing conditions to the greatest extent practicable.

Nearly all access roads will be constructed of gravel and/or locally available soil, and as such will be permeable. Any runoff from the roads themselves will be conveyed into swales/brow ditches parallel to the road. Swale flows will be conveyed to surrounding existing drainage features, where they will return to the existing drainage patterns. Access roads over 10% will be required to be paved based on the County of San Diego Fire Department requirements. Any short distances of paved roads will be drained similarly to the gravel roads.

A complete discussion of the Project drainage is completed in the report Preliminary EIS/EIR Drainage Report, dated September 2010.

3.3 HYDROMODIFICATION

Based on the County of San Diego Major Storm Water Management Plan form this Project is required to complete a Hydromodification Plan (HMP). However, after discussions with the County of San Diego it was determined that the Project would not be subject to the County hydromodification requirements given the location of Project County of San Diego jurisdiction lands outside of Phase I and Phase II NPDES permits. Therefore, the General Construction Permit post construction BMP criteria will apply. Alterations to the natural watershed and stream processes (hydromodification) from Project development are the main concern in the General Construction Permit. In order to apply and quantify post construction BMP requirements aimed at addressing hydromodification, a Post-Construction Water Balance Calculator is being created by the SWRCB. Final implementation of these requirements will commence in September of 2012, with further refinements to the Post-Construction Water Balance Calculator anticipated prior to implementation.

Given the current planning stage of the Project and the preliminary Post-Construction Water Balance Calculator, specific sizing and application of the General Construction Permit post construction BMPs is limited to recommendations in this report. All future design work will consider the General Construction Permit sizing requirements for included features intended to address hydromodification.

4.0 SITE DESIGN BMPS

Site design requirements for the Project are taken from the County of San Diego Storm Water Management Plan Form and are discussed are presented below. There are no specific site design BMPs identified in the General Construction Permit other than those shown on the Water Balance Calculator. This being the case, site design BMPs listed below are all those listed on the County of San Diego Storm Water Management Plan Form, however some may not apply given the limited amount of development proposed. Since the Project is in the preliminary stages of planning, site design BMPs could change as planning progresses.

<u>Principle 1: Maintain Pre-Development Rainfall Runoff Characteristics</u>

1. Locate the Project and road improvement alignments to avoid or minimize impacts to receiving waters or to increase the preservation of critical (or problematic) areas such as floodplains, steep slopes, wetlands, and areas with erosive or unstable soil conditions.
2. Minimize the Project impervious footprint.
3. Conserve natural areas.
4. Where landscape is proposed drain rooftops, impervious sidewalks, walkways, trails and patios into adjacent landscaping.
5. Design and locate roadway structures and bridges to reduce the amount of work in live streams and minimize the construction impacts.
6. Implement the following methods to minimize erosion from slopes:
    - Disturb existing slopes only when necessary;
    - Minimize cut and fill areas to reduce slope lengths;
    - Incorporate retaining walls to reduce steepness of slopes or to shorten slopes;
    - Provide benches or terraces on high cut and fill slopes to reduce concentration of flows;
    - Round and shape slopes to reduce concentrated flow;
    - Collect concentrated flows in stabilized drains and channels.

Project development will incorporate nearly all of the Principle 1 criteria. Access road development and improvements are sited to follow existing roads to the maximum extent practicable and typically follow ridgelines to limit the amount of grading and the amount of disturbed vegetated areas. Overall areas disturbed by the Project are kept to the minimum required for construction and operation of the facilities, and limit the amount of grading, crossings of drainages, and removal of vegetation. All improvements will drain to vegetated brow ditches/swales rather than a hardened storm drain system. All cut and fill slopes will include terraces as required by the San Diego County Grading Ordinances. Concentrated flows from slopes will be collected in swales/brow ditches for conveyance to existing drainage facilities.

<u>Principle 2: Protect Slopes and Channels</u>

1. Minimize disturbances to natural drainages.
2. Convey runoff safely from the tops of slopes
3. Vegetate slopes with native or drought tolerant vegetation.
4. Stabilize permanent channel crossings.
5. Install energy dissipaters, such as riprap, at the outlets of new storm drains, culverts, conduits, or channels that enter unlined channels in accordance with applicable specifications

to minimize erosion. Energy dissipaters shall be installed in such a way as to minimize impacts to receiving waters.

6. Other design principles which are comparable and equally effective.

Preliminary planning for the Project has not identified specific slope and channel protection measures, but Principle 2 criteria will be implemented. Project planning will limit the number of unnecessary drainage crossings, but will include engineered crossings at locations where crossings are required. All drainage crossing will be completed such that San Diego County Drainage Design Manual criteria are met, including outfall energy dissipation design guidelines. Any slope grading will be completed such that direction and impacts of runoff are carefully controlled with brow ditches, grading methods, or other similar alternatives. Additional CASQA site design BMP information is included in Appendix D.

4.1 LOW IMPACT DEVELOPMENT FEATURES

LID features requirements are identified in the Major SWMP form and are discussed in further detail in the County LID Handbook. LID feature requirements reviewed for the Project are as follows:

- Conserve natural areas, soils, and vegetation
- Preserve well draining soils (Type A or B)
- Preserve Significant Trees
- Minimize disturbance to natural drainages
- Set-back development envelope from drainages
- Restrict heavy construction equipment access to planned green/open space areas
- Minimize and disconnect impervious surfaces
- Preserve well draining soils (Type A or B)
- Preserver Significant Trees
- Minimize soil compaction
- Restrict heavy construction equipment access to planned green/open space areas
- Re-till soils compacted by construction vehicles/equipment
- Collect and reuse upper soil layers of development site containing organic materials
- Drain runoff from impervious surfaces to pervious areas
- Curb-cuts to landscaping
- Rural swales
- Concave median
- Cul-de-sac landscaping design
- LID parking lot design
- Permeable pavements

- Curb-cuts to landscaping
- LID driveway, sidewalk, bike-path design
- Permeable pavements
- Pitch pavements toward landscaping
- LID Building Design
- Cisterns and rain barrels
- Downspout to swale
- Vegetated roofs
- LID landscaping design
- Soil amendments
- Reuse of native soils
- Smart irrigation systems
- Street trees

Project development proposes to utilize applicable LID features. Nearly all runoff generated by the Project site will discharge to surrounding naturally landscaped areas, which represents a majority of the previously listed features. Surrounding landscaping includes brow ditches or vegetated swales. Potential additional LID features considered are bioretention facilities and buffer strips. Disturbances to existing natural features will be limited during Project development by concentrating development on areas that have already been disturbed, typically existing roads. Soil compaction will be minimized by having well planned out access paths between the turbine sites, which will limit the disturbed areas impacted by the larger cranes required for turbine construction. Impervious areas will all drain to surrounding naturally vegetated areas. No significant impermeable parking lots, sidewalks, roads, or other impermeable access features are planned for the Project, as nearly all surface improvements will be gravel or compacted dirt. All landscaping will be completed to match the existing surrounding conditions and will be composed of similar slopes and drought tolerant native species of plants.

5.0 SOURCE CONTROL BMPS

Source control requirements are discussed below. Similar to site design the County of San Diego guidelines were used for BMP discussion, as General Construction Permit criteria are not very descriptive. Given the preliminary stage of Project development the following source control BMPs are recommended and will be updated during planning to better reflect utilized source control BMPs. Future site planning will be subject to standards in effect at the time of development.

<u>Principle 3: Provide Storm Drain System Stenciling and Signage</u>

1. All storm drain inlets and catch basins within the Project area shall have a stencil or tile placed with prohibitive language (such as: "NO DUMPING – I LIVE IN <<name receiving water>>") and/or graphical icons to discourage illegal dumping.
2. Signs and prohibitive language and/or graphical icons, which prohibit illegal dumping, must be posted at public access points along channels and creeks within the Project area.

Project development will not likely contain any storm drain inlets, however any inlets constructed will contain the standard stenciling and signage packages. All access roads to the turbines are intended to be private and as such will not provide public access points to the natural drainage systems.

<u>Principle 4: Design Outdoors Material Storage Areas to Reduce Pollution Introduction</u>

1. Hazardous materials with the potential to contaminate urban runoff shall either be: (1) placed in an enclosure such as, but not limited to, a cabinet, shed, or similar structure that prevents contact with runoff or spillage to the stormwater conveyance system; or (2) protected by secondary containment structures such as berms, dikes, or curbs.
2. The storage area shall be paved and sufficiently impervious to contain leaks and spills
3. The storage area shall have a roof or awning to minimize direct precipitation within the secondary containment area.

Maintenance and operation facilities are intended to safely house any materials that could potentially pollute storm water in a dedicated indoor facility. All operation and maintenance materials will be located in these structures.

<u>Principle 5: Design Trash Storage Areas to Reduce Pollution Introduction</u>

1. Paved with an impervious surface, designed not to allow run-on from adjoining areas, screened or walled to prevent off-site transport of trash; and,
2. Provide attached lids on all trash containers that exclude rain, or roof or awning to minimize direct precipitation.

Similar to material storage, trash storage areas will utilize indoor trash storage or trash containers with covers to limit direct precipitation and runoff.

<u>Principle 6: Use Efficient Irrigation Systems and Landscape Design</u>

1. Employ rain shutoff devices to prevent irrigation after precipitation.
2. Design irrigation systems to each landscape area's specific water requirements.

3. Use flow reducers or shutoff valves triggered by a pressure drop to control water loss in the event of broken sprinkler heads or lines.
4. Employ other comparable, equally effective, methods to reduce irrigation water runoff.

Landscaping to be incorporated in Project design is likely to be similar to exiting vegetation and as such will not require any irrigation. However, any irrigation that would be required, either short term (for vegetation establishment) or permanent would be constructed with rain shutoff devices, flow reducers, and specific design for water requirements. Additional CASQA source control BMP information is included in Appendix D.

6.0 INDIVIDUAL PRIORITY PROJECT BMPS

The County of San Diego SUSMP requires specific BMPs for private roads, residential driveways & guest parking, dock areas, maintenance bays, vehicle wash areas, equipment wash areas, outdoor processing areas, surface parking areas, fueling areas, or steep hillside landscaping. Preliminary site planning includes private roads, surface parking areas, and steep hillside landscaping. Applicable individual priority project BMP requirements are presented below with discussion of the utilized BMPs. These BMPs are similar to CASQA BMP handbook guidelines.

6.1 PRIVATE ROADS

The design of private roadway drainage requires at least one of the following:

- Rural swale system: street sheet flows to vegetated swale or gravel shoulder, curbs at street corners, culverts under driveways and street crossings;
- Urban curb/swale system: street slopes to curb, periodic swale inlets drain to vegetated swale/biofilter
- Dual drainage system: first flush captured in street catch basins and discharged to adjacent vegetated swale or gravel shoulder, high flows connect directly to stormwater conveyance system.
- Other methods which are comparable and equally effective within the Project.

Current Project planning uses gravel or compacted dirt permeable roads with parallel swale/brow ditch drainage facilities. Precipitation will sheet flow off the private roads where it will be collected in the swale/brow ditch system. There are no hardened storm drains facilities planned for the proposed private roads at this time.

6.2 SURFACE PARKING AREAS

To minimize the offsite transport of pollutants from parking areas, the following design concepts shall be considered, and incorporated and implemented where determined applicable and feasible by the County:

- Where landscaping is proposed in surface parking areas, incorporate landscape areas into the drainage design; or
- Overflow parking (parking stalls provided in excess of the County's minimum parking requirements) may be constructed with permeable paving.
- Other design concepts which are comparable and equally effective.

Surface parking areas proposed for Project development are all small areas intended for accommodating only several vehicles at a time. Parking areas will be constructed of gravel or compacted dirt and will sheet flow to surrounding landscaping. There is no hardened storm drain features proposed for the Project at this time.

6.3 STEEP HILLSIDE LANDSCAPING

Hillside areas, as defined in the County of San Diego SUSMP, that are disturbed by Project development shall be landscaped with deep-rooted, drought tolerant plant species selected for erosion control, satisfactory to the County.

Hillside areas disturbed during Project development will be revegetated with drought tolerant native species to stabilize the new slopes. Vegetation will be selected based on its ability to provide erosion resistance to the slopes as well as survive the arid local climate.

7.0 TREATMENT CONTROL BMPS

7.1 STRUCTURAL TREATMENT CONTROL BMP DISCUSSION

Discussions with the County of San Diego identified that Project development would not specifically require treatment BMPs based on the County guidelines. However, based on the Project location, General Construction Permit post-construction BMPs will be required. General Construction Permit post-construction BMP objectives are to reduce the impacts from project development on existing natural drainages. These impacts are typically increased channel erosion or deposition resulting from changes in runoff patterns from the Project site, also known as hydromodification. It has been found that the flows that actually cause the most impact to existing drainages are associated with the high frequency lower volume storms, which is the focus of the General Construction Permit. Project impacts are quantified in the General Construction Permit by a Water Balance Calculator, which identifies the changes in Project runoff and allows for mitigation of these impacts through numerous LID and local detention features. Water Balance Calculator analysis gives mitigation credit to the following Project features:

- Porous pavement,
- Tree planting,
- Downspout disconnection,
- Impervious area disconnection,
- Green roof
- Vegetated swales,
- Rain barrels/cisterns, and
- Soil quality.

Project development proposes to use vegetated swales, downspout disconnection, and potentially several detention basins for the operation and maintenance area and/or substation areas. Additionally, all impervious areas will be disconnected and will be drained via natural features. A comparison of these features with the County of San Diego SUSMP requirements was completed in order to better identify mitigation benefits. Table 5 contains Table 2-3: Treatment Control Selection Matrix, from the County of San Diego SUSMP.

Table 5: Groups of Pollutants and Relative Effectiveness of Treatment Facilities

Pollutant of Concern	**Bioretention Facilities (LID)**	**Settling Basins (Dry Ponds)**	**Wet Ponds and Wetlands**	**Infiltration Facilities or Practices (LID)**	**Media Filters**	**High-rate biofilters**	**High-rate media filters**	**Trash Rack & Hydro-dynamic Devices**
Course Sediment and Trash	High	High	High	High	High	High	High	High
Pollutants that tend to associate with fine particles during treatment	High	High	High	High	High	Medium	Medium	Low
Pollutants that tend to be dissolved following treatment	Medium	Low	Medium	High	Low	Low	Low	Low

There are no primary pollutants of concern for the Project, and the Project will not contribute pollutants to a 303 (d) list water body, with the possible exception of Morena Reservoir. With no primary pollutants of concern, the County of San Diego SUSMP requires the Project to focus on the secondary pollutants of concern. Secondary pollutants of concern are trash and oil and grease; which represent course sediment and trash as well as pollutants that tend to associate with fine particles during treatment. Table 5 identifies settling basins and LID bioretention facilities as having high removal efficiencies for all pollutants of concern. Based on this, the selection of swales/brow ditches and detention basins for General Construction Permit post-construction BMP requirements, also meets the intent of the County of San Diego SUSMP.

Further design of these post-construction BMPs will be required during final Project engineering. As the planning process progresses more detail will be available as to the opportunities and locations for these features. Exhibit C includes a BMP Map which defines potential locations for treatment BMPs as well as typical site design and source control BMPs. The BMP Map is only intended to be representative of potential or typical BMP locations and is not intended to exclude additional locations of features. Additional CASQA BMP information is located in Appendix D.

Responsible parties for the capital costs associated with construction of the treatment control BMPs are presented in Table 6.

Table 6: Treatment Control BMP Capital Cost Responsible Party

Treatment Control BMP	Responsible Party
Detention Basins	Iberdrola
Swales/Brow Ditches	Iberdrola

8.0 STORM WATER BMP MAINTENANCE

In accordance with Section 5 of the County of San Diego SUSMP the Project BMPs will be classified as First Category. BMPs will largely “maintain themselves” via the natural process of vegetation growth cycles. Vegetated swales/natural drainages and open spaces for impervious area disconnection will be seeded with local naturally occurring plant types, which will be allowed to grow naturally in these facilities. Permeable paving surfaces will be maintained by Iberdrola to provide uniform access roads. Any erosion issues associated with the unvegetated drive surface will be immediately addressed to limit any sediment discharge from the site. Table 7 defines the anticipated BMP responsible parties.

Table 7: BMP Maintenance Responsibility

Treatment Control BMP	Responsible Party
Detention Basins	Iberdrola
Swales/Brow Ditches	Iberdrola

All operation and maintenance required by these BMPs will be the responsibility of Iberdrola. More specific operation and maintenance of the BMPs will be established during final Project design.

9.0 CONCLUSION

Based on the currently applicable water quality requirements, an analysis of the potential impacts was completed for the Tule Wind Project. This analysis determined that the Project would have a low potential to result in water quality impacts to the surrounding water bodies. Minimal impervious area increases are proposed with Project disturbance placement intended to limit the impacts to surrounding water bodies. Based on the minimal level of impervious surfaces proposed as part of the project and implementation of applicable site design BMPs, source control BMPs, individual priority project BMPs, treatment control BMPs, and storm water BMP maintenance, the project will not substantially degrade water quality. Mitigation measures are implemented to the maximum extent practicable to address these limited numbers of potential impacts. Operation and maintenance of the BMPs should be minimal, due to their natural operation conditions, with responsibility for these features performance over the life of the Project being the developers.

APPENDIX A – Preliminary Project Details

Typical Turbine Schematic

Typical Turbine Site

Typical Access Road Sections

Typical Substation Facility

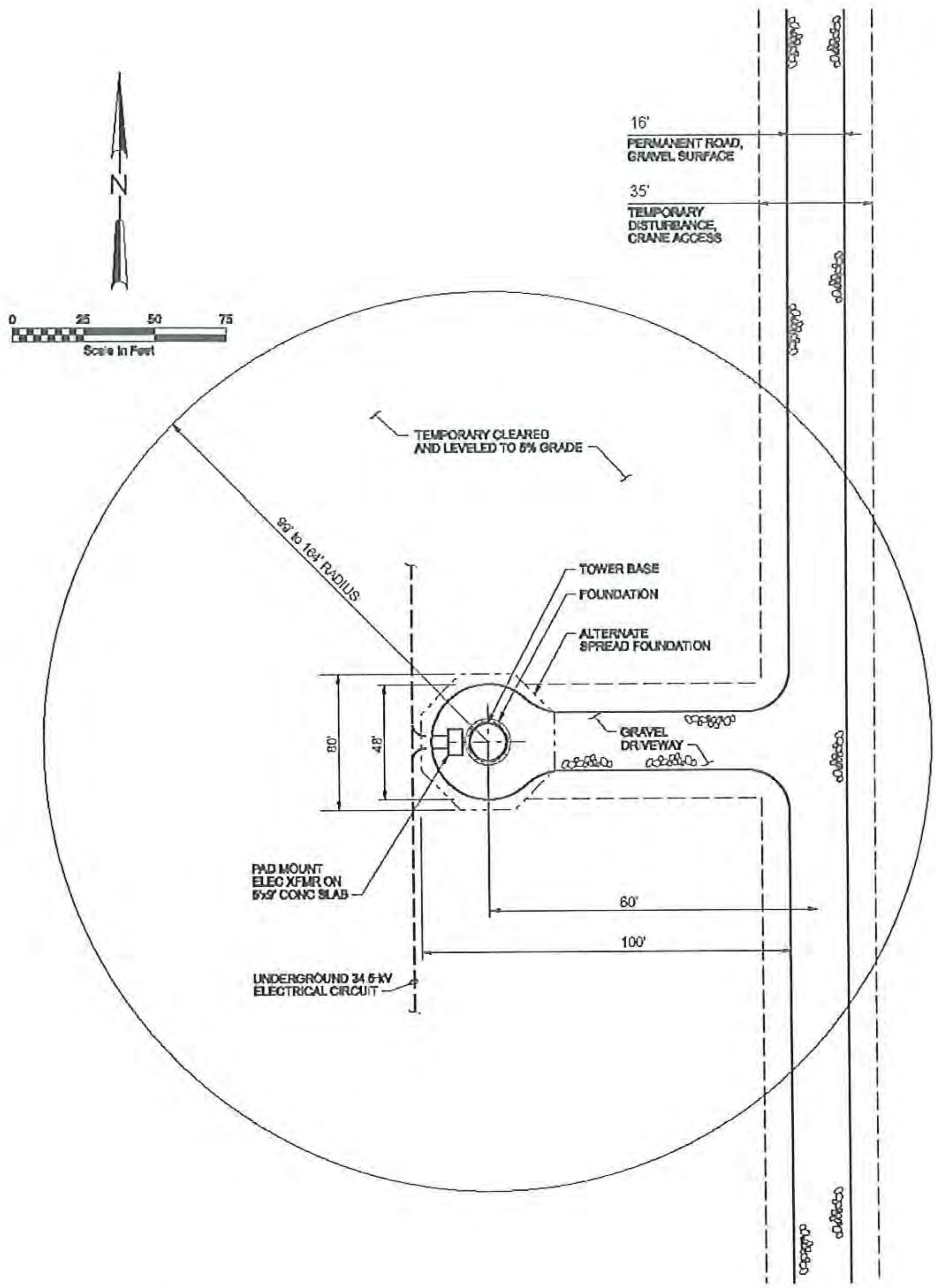
Typical Operation and Maintenance Facility Site

Typical Operation and Maintenance Facility Elevations

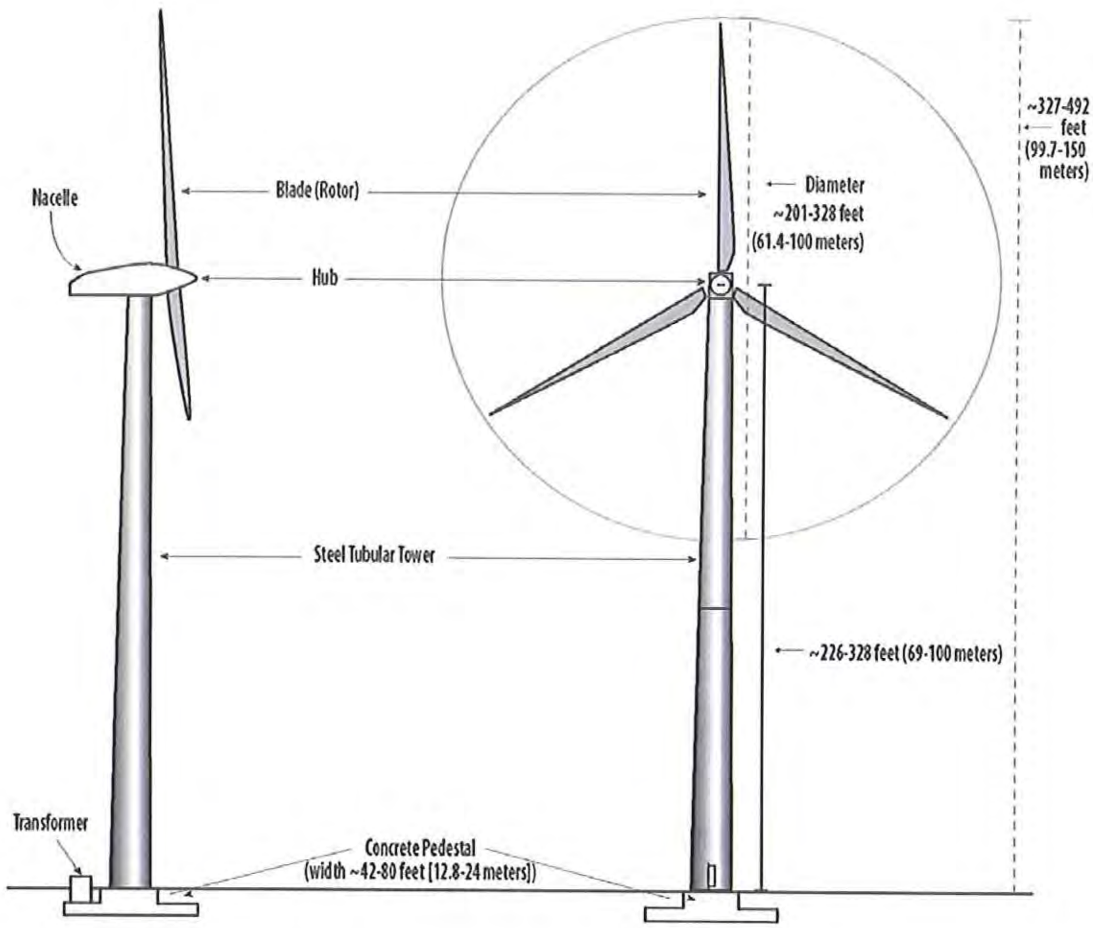
Typical Transmission Power Pole

Typical Collector Line Power Pole

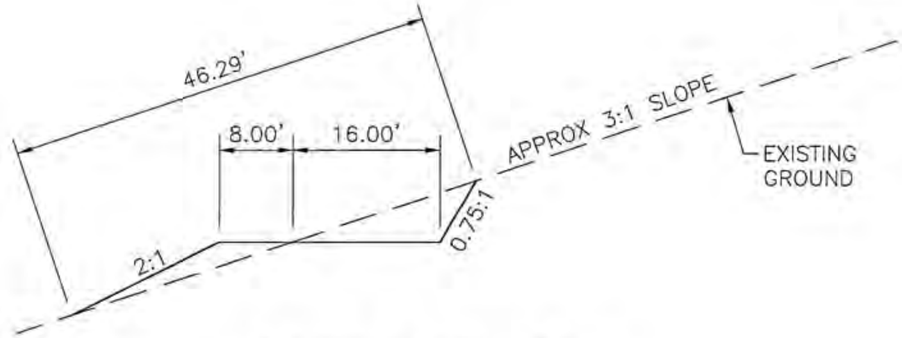
Typical Buried Collector Line



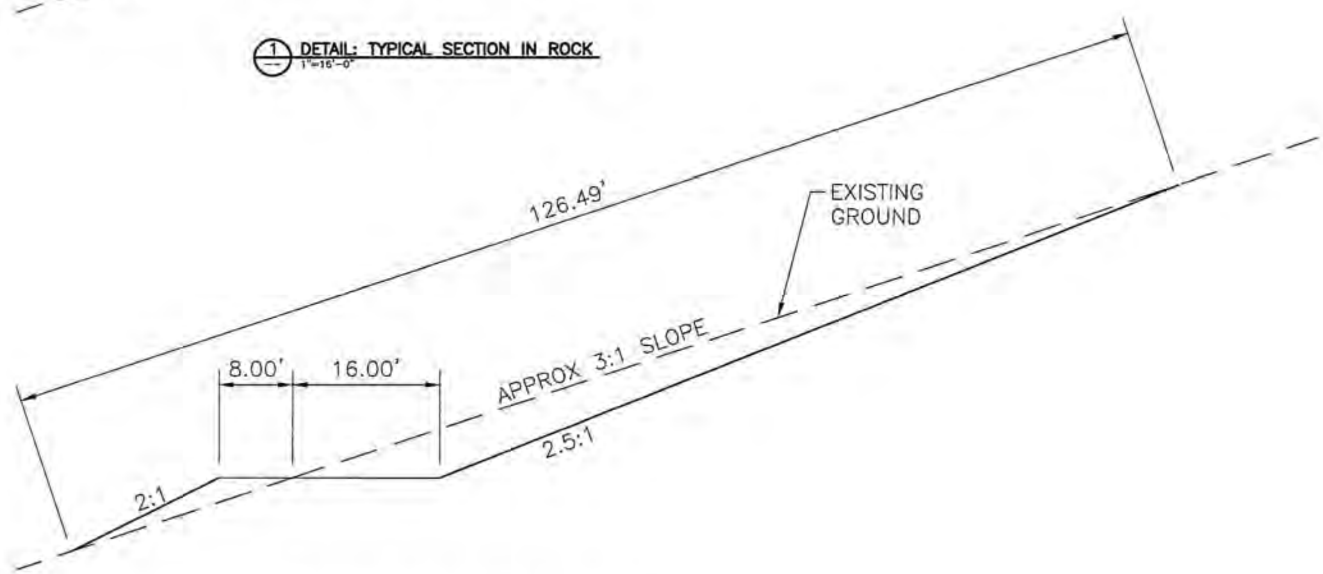
Turbine Site



Turbine Schematic

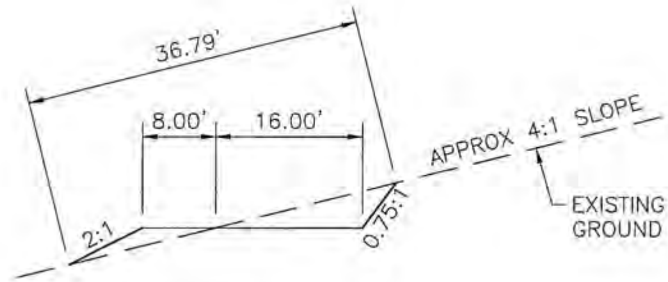


DETAIL: TYPICAL SECTION IN ROCK
1"=16'-0"

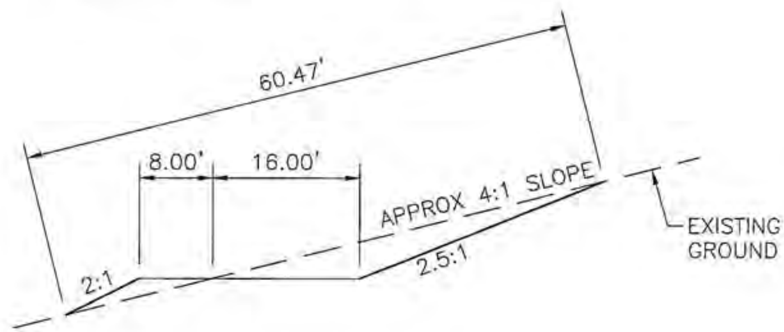


DETAIL: TYPICAL SECTION IN SOIL
1"=16'-0"

Typical Access Road Cross Sections



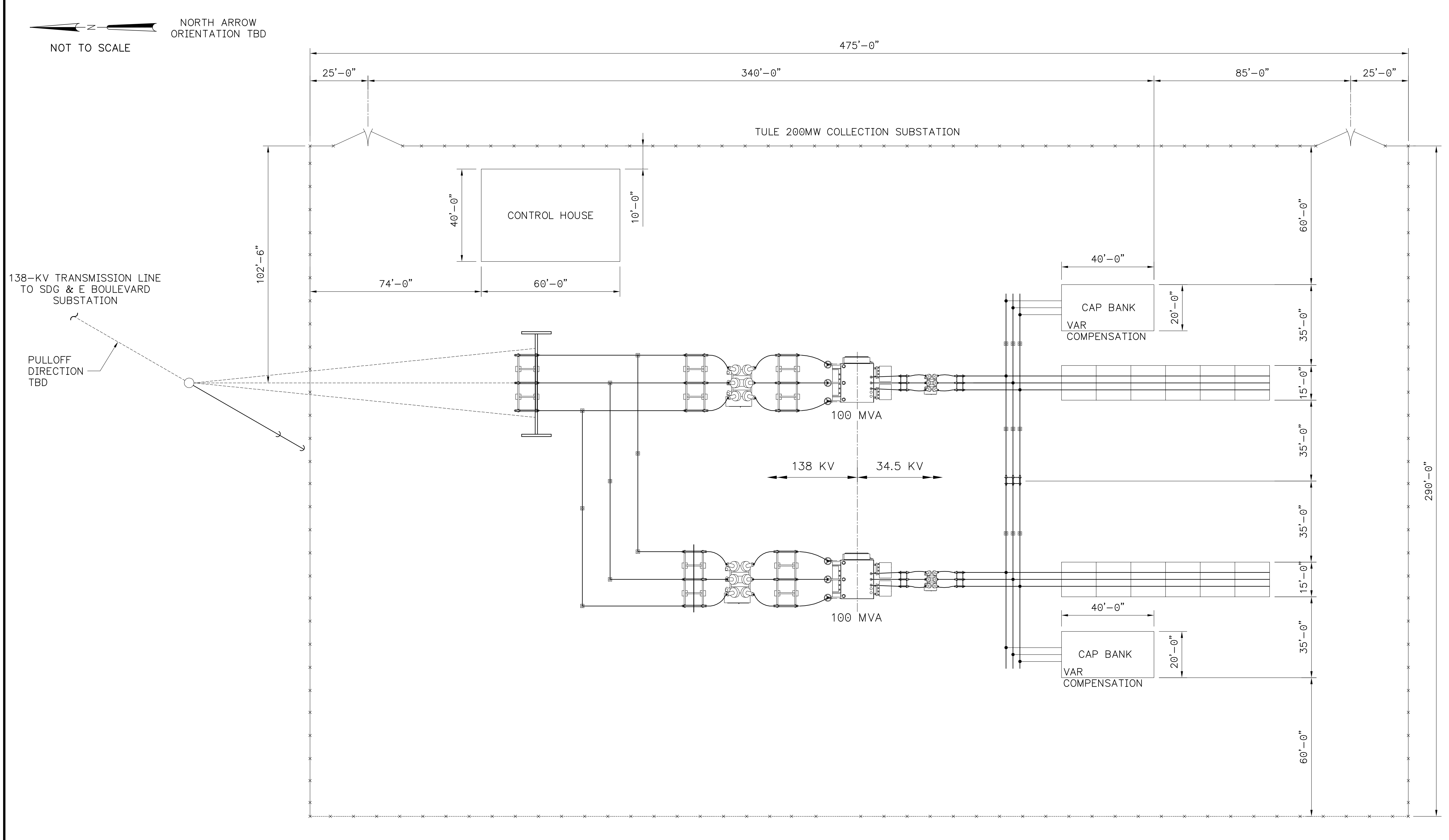
1 DETAIL: TYPICAL SECTION IN ROCK



2 DETAIL: TYPICAL SECTION IN SOIL

Typical Access Road Cross Sections

10/20/2009 11:12 AM TWEBSTER Z:\TWW_VAN\IBERDROLA\TULE\2009 ASSISTANCE\DWGS\FIGURE4.DWG



TriAxis Engineering, Inc.

DSGN	J KING
DR	FIGURE4.DWG T WEBSTER
CHK	G ORMSBY
APVD	G ORMSBY

NO.	DATE	REVISION	BY	APVD

REUSE OF DOCUMENTS

THIS DOCUMENT, AND THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, IS THE PROPERTY OF TRIAXIS ENGINEERING, INC. AND IS NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF TRIAXIS ENGINEERING, INC.

VERIFY SCALES

BAR IS ONE HALF INCH ON ORIGINAL DRAWING

0 1/2"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

TULE SUBSTATION

IBERDROLA RENEWABLES

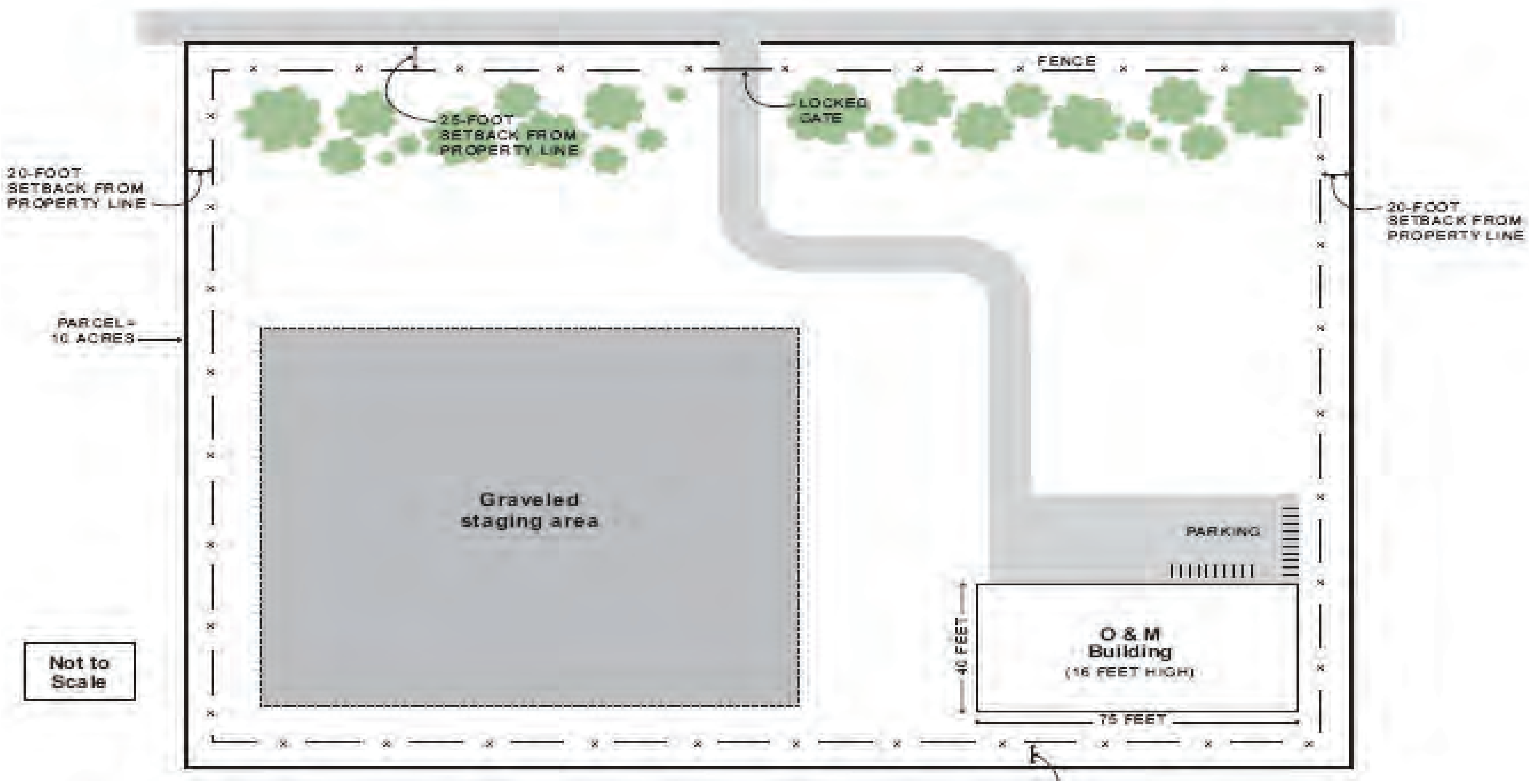
TULE WIND PROJECT

FIGURE 4
200MW COLLECTION SUBSTATION
PLAN VIEW

SHEET	
DWG NO.	FIGURE4
DATE	DEC 2009
PROJ NO.	Y8773

PRELIMINARY

Source: Iberdrola, 2009 | G:/Projects\IberdrolaRenew_424914\TuleWindEnergy_115965\14_00_GIS_MODELS\14_02_Graphics\14_02_01_docs\Ltr_Landscp_master.ai | Last Updated : 12-24-2009



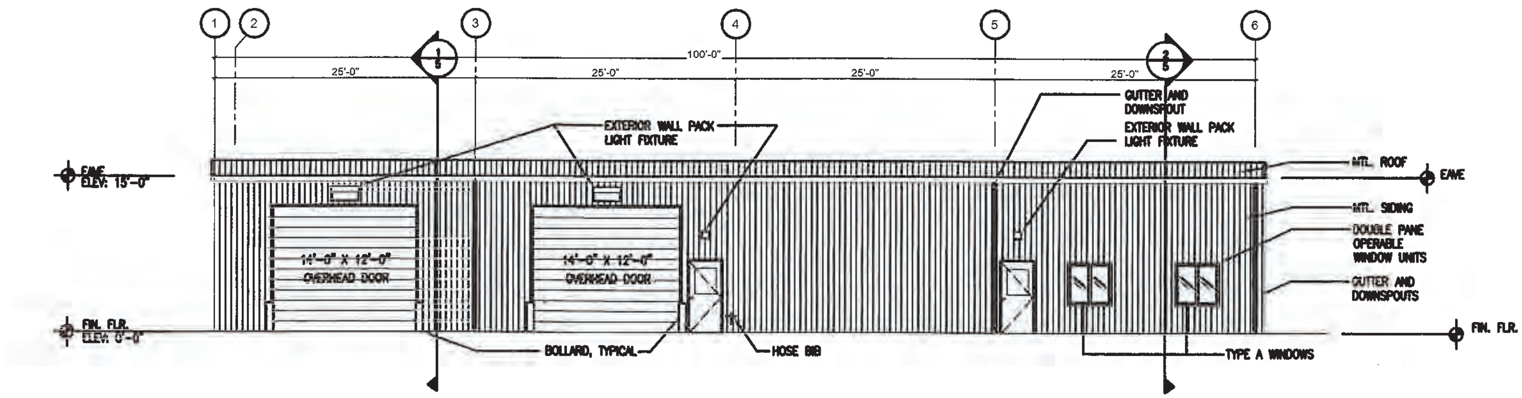
Typical Operations and Maintenance Facility Site

FIGURE 2.0-9a

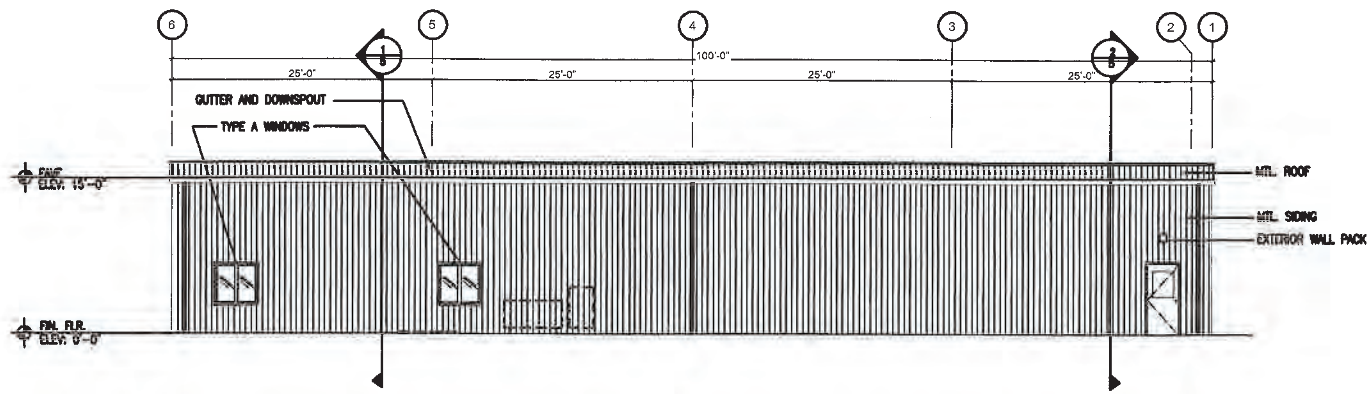
Iberdrola | Tule Wind Project | Applicant's Environmental Document

HDR ONE COMPANY | *Many Solutions*℠

Source: Iberdrola, 2009 | G:/Projects\IberdrolaRenew_424914\TuleWindEnergy_115965\14_00_GIS_MODELS\14_02_Graphics\14_02_01_docs\Ltr_Landscp_master.ai | Last Updated : 12-24-2009



1 **SOUTH ELEVATION**

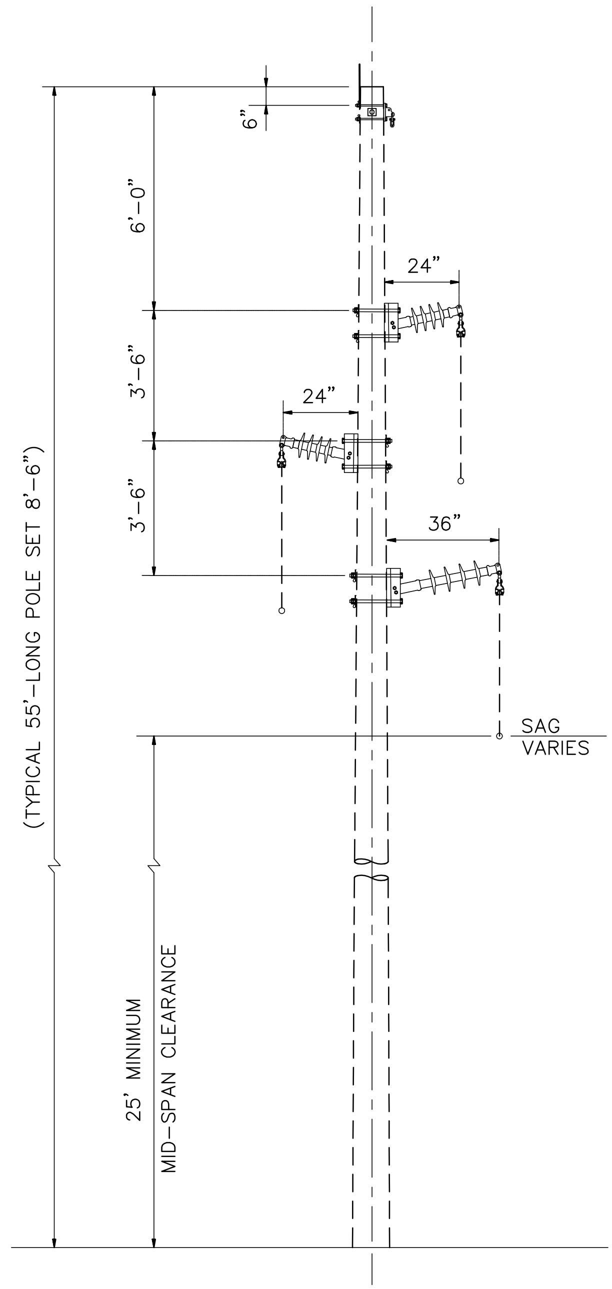


2 **NORTH ELEVATION**

Typical Operations and Maintenance Facility Elevations

FIGURE 2.0-9b

HDR ONE COMPANY | *Many Solutions* SM



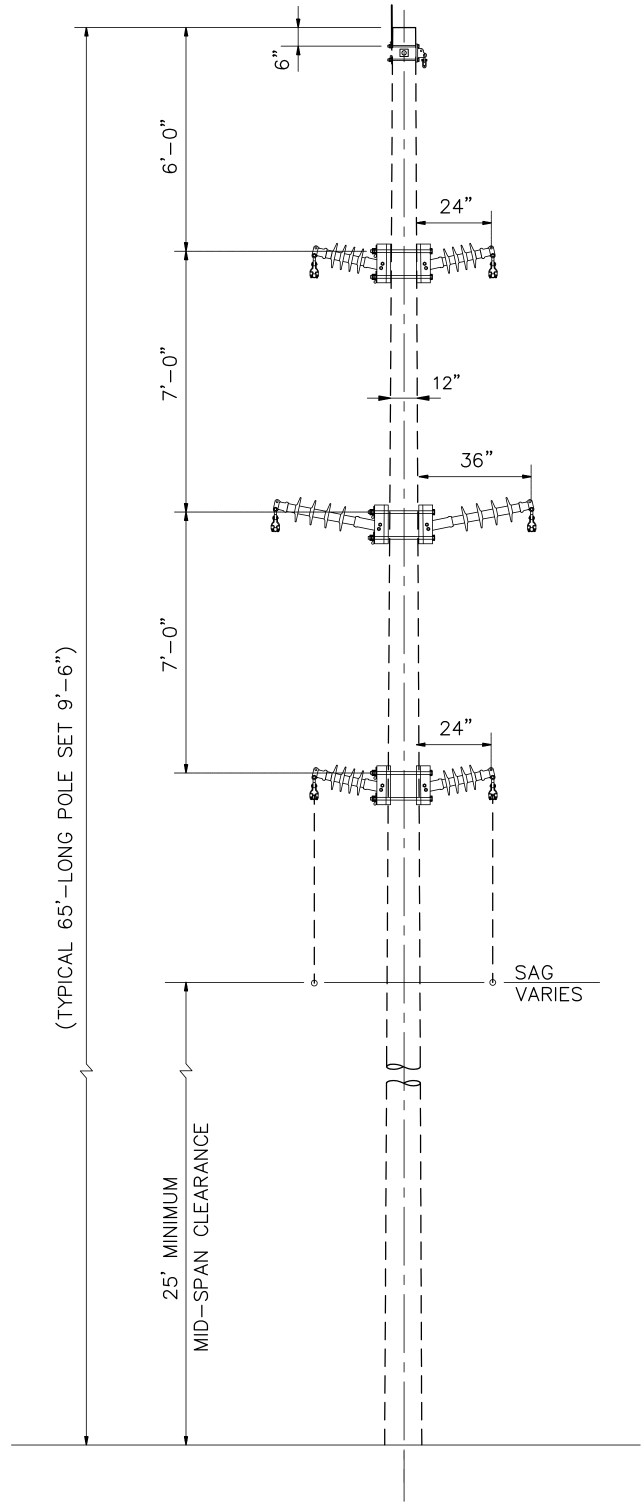
DESIGN ASSUMPTIONS:

- 1590 KCMIL "COREOPSIS" AAC
- 280' MAX SPAN

NOTES:

1. STRUCTURE DIMENSIONS ARE APPROXIMATE. ACTUAL DIMENSIONS MAY VARY.
2. DIMENSIONS ARE TO ATTACHMENT HOLES.
3. DRAWING IS NOT TO EXACT SCALE

IBERDROLA TULE WIND PROJECT	TYPICAL 34.5-KV HORIZONTAL LINE POST TANGENT SINGLE-CIRCUIT CONFIGURATION			
TriAxis Engineering, Inc.	DSGN MCF	DR JHR	DATE FEB 2010	FIG 1



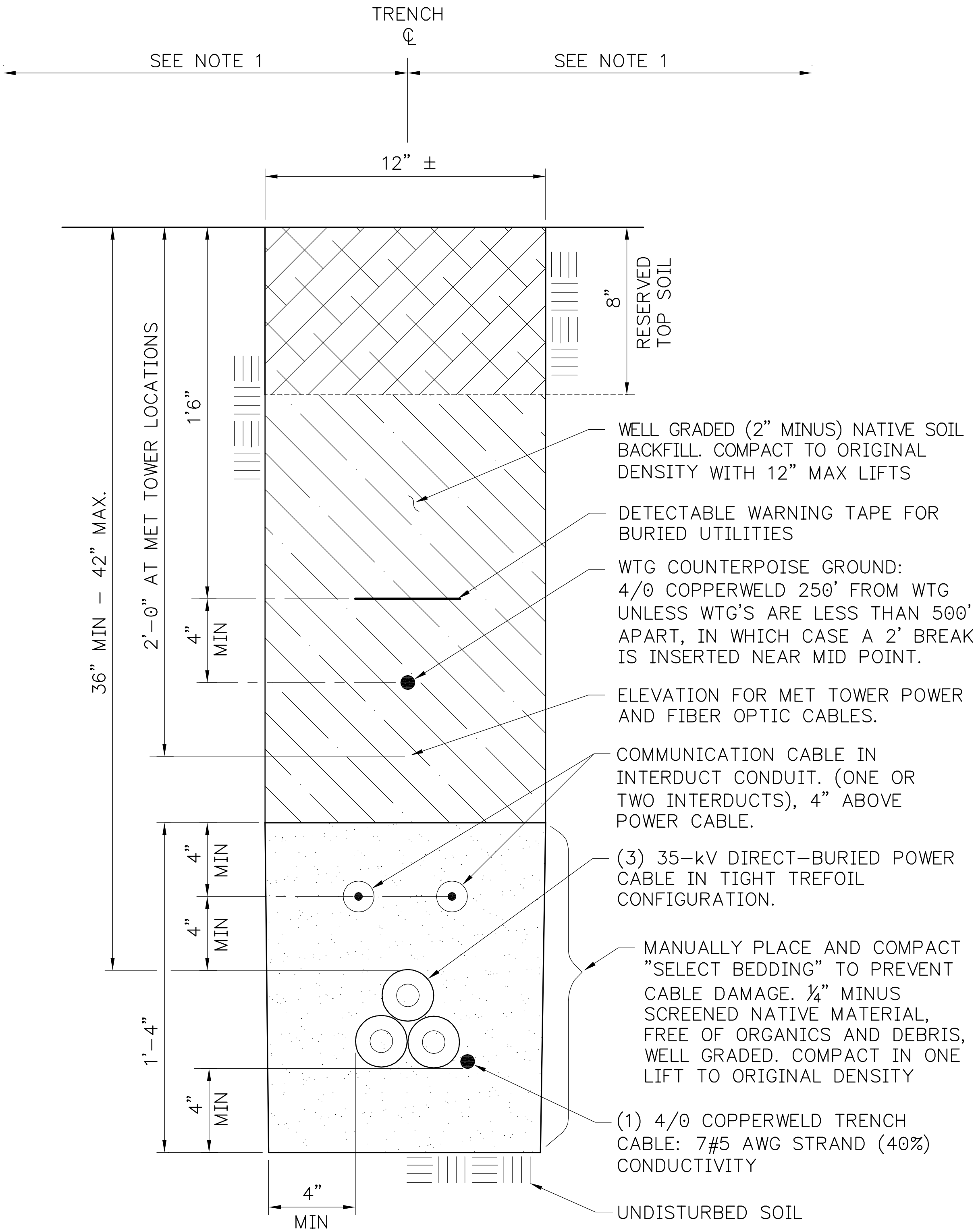
DESIGN ASSUMPTIONS:

- 1590 KCMIL "COREOPSIS" AAC
- 280' MAX SPAN

NOTES:

1. STRUCTURE DIMENSIONS ARE APPROXIMATE. ACTUAL DIMENSIONS MAY VARY.
2. DIMENSIONS ARE TO ATTACHMENT HOLES.
3. DRAWING IS NOT TO EXACT SCALE

IBERDROLA TULE WIND PROJECT	TYPICAL 34.5-KV HORIZONTAL LINE POST TANGENT DOUBLE-CIRCUIT CONFIGURATION			
TriAxis Engineering, Inc.	DSGN MCF	DR JHR	DATE FEB 2010	FIG 2



NOTES:

1. EACH 3-PHASE CABLE TRENCH SHALL BE SEPARATED FROM ALL OTHER CABLE TRENCHES BY 10'-6" MINIMUM, CENTERLINE-TO-CENTERLINE UNLESS OTHERWISE NOTED ON DRAWINGS.
2. ROCKS SHALL NOT COME IN CONTACT WITH CABLES.

IBERDROLA RENEWABLES TULE WIND PROJECT	FIGURE 2 DIRECT BURIED 34.5-KV UNDERGROUND CABLE TRENCH DETAIL	TriAxis Engineering, Inc.

APPENDIX B – County of San Diego StormWater Intake Form for Development Projects

County of San Diego Stormwater Intake Form for Development Projects

County of San Diego

STORMWATER INTAKE FORM FOR DEVELOPMENT PROJECTS

This form must be completed in its entirety and accompany applications for any of the discretionary or ministerial permits and approvals referenced in Sections 67.803(c)(1) and 67.803(c)(2) of the County of San Diego Watershed Protection, Stormwater Management and Discharge Control Ordinance (WPO).

STEP 1: IDENTIFY RELEVANT PROJECT INFORMATION

Applicant Name: Andrew Linehan		Contact Information: Jeffrey Durocher
Project Address: Multiple Properties	APN(s): See APN list	Permit Application #:

STEP 2: DETERMINE PRIORITY DEVELOPMENT PROJECT STATUS

WPO Section 67.802(w) defines the criteria for determining whether your project is considered a Priority Development Project (PDP). If you answer "Yes" to any of the questions below, your project is a PDP subject to review and approval of a Major Stormwater Management Plan (SWMP). If you answer "No" to all of the questions below, your project is subject to review and approval of a Minor SWMP.

1. *Residential subdivision of 10 or more dwelling units (Single-family, Multi-family, Condo, or Apartment Complex) ...... Yes No* (No circled)
2. *Commercial development that includes development of land area greater than one (1) acre .... Yes No* (No circled)
3. *Industrial development greater than one (1) acre .... Yes No* (No circled)
4. *Automotive repair shop .... Yes No* (No circled)
5. *Restaurant or restaurant facilities with an area of development of 5,000 square feet or greater .... Yes No* (No circled)
6. *On a steep hillside (>25% natural slope) <u>AND</u> proposes 5,000 square feet of impervious surface or more, or includes grading of any natural slope >25%* [1] *.. Yes No* (Yes circled)
7. *Located within 200 feet of an Environmentally Sensitive Area <u>AND</u> creates 2,500 square feet or more of impervious surface or increases the area of imperviousness of a site to more than 10% of its naturally occurring condition* [1] [2] *...... Yes No* (No circled)
8. *A parking lot that is 5,000 square feet or greater <u>OR</u> proposes at least 15 new parking stalls .... Yes No* (No circled)
9. *Streets or roads that create a new paved surface that is 5,000 square feet or greater .... Yes No* (No circled)
10. *Retail gasoline outlet .... Yes No* (No circled)

[1] In lieu of a Major SWMP, Ministerial Permit Applications for residential dwellings/additions on an existing legal lot answering "Yes" may be able to utilize the Minor Stormwater Management Plan upon approval of a county official. Please note that upon further analysis, staff may determine that a Major SWMP will be required.
[2] A County technician will assist you in determining whether your project is located within 200 feet of an Environmentally Sensitive Area.

STOP **If you answered "Yes" to any of the questions, please complete a Major SWMP for your project.**
Instructions and an example of the form can be downloaded from http://www.co.san-diego.ca.us/dpw/watersheds/land_dev/susmp.html

If you answered "NO" to all of the questions above, please complete a Minor SWMP for your project.
Instructions and an example of the form can be downloaded from http://www.sdcounty.ca.gov/dplu/docs/LUEG-SW.pdf

STEP 3: SIGN AND DATE THE CERTIFICATION

<u>APPLICANT CERTIFICATION</u>: I have read and understand that the County of San Diego has adopted minimum requirements for managing urban runoff, including stormwater, from construction and land development activities. I certify that this intake form has been completed to the best of my ability and accurately reflects the project being proposed. I also understand that non-compliance with the County's WPO and Grading Ordinance may result in enforcement by the County, including fines, cease and desist orders, or other actions.

Applicant : *Date:*

APPENDIX C – PROJECT EXIBITS

Exhibit A – Existing Conditions Drainage Map

Exhibit B – Proposed Conditions Drainage Map

Exhibit C – BMP Map

HDR ONE COMPANY | *Many Solutions*

Existing Conditions Drainage Map

EXHIBIT A

Tule Wind Project | EIR EIS Strom Water Management Plan Report

HDR ONE COMPANY | *Many Solutions*

Proposed Conditions Drainage Map

EXHIBIT B

Tule Wind Project | EIR EIS Storm Water Management Plan Report

HDR ONE COMPANY | Many Solutions

BMP Map

EXHIBIT C

Tule Wind Project | EIR EIS Storm Water Management Plan Report

APPENDIX D – ADDITIONAL BMP INFORMATION

CASQA Site Design and Facility Design

CASQA Site Design and Landscape Planning

CASQA Vegetated Swale

CASQA Extended Detention Basin

Section 3
Site and Facility Design for Water Quality Protection

3.1 Introduction

Site and facility design for stormwater quality protection employs a multi-level strategy. The strategy consists of: 1) reducing or eliminating post-project runoff; 2) controlling sources of pollutants; and 3), if still needed after deploying 1) and 2), treating contaminated stormwater runoff before discharging it to the storm drain system or to receiving waters.

This section describes how elements 1), 2), and 3) of the strategy can be incorporated into the site and facility planning and design process, and by doing so, eliminating or reducing the amount of stormwater runoff that may require treatment at the point where stormwater runoff ultimately leaves the site. Elements 1) and 2) may be referred to as "source controls" because they emphasize reducing or eliminating pollutants in stormwater runoff at their source through runoff reduction and by keeping pollutants and stormwater segregated. Section 4 provides detailed descriptions of the BMPs related to elements 1) and 2) of the strategy. Element 3) of the strategy is referred to as "treatment control" because it utilizes treatment mechanisms to remove pollutants that have entered stormwater runoff. Section 5 provides detailed descriptions of BMPs related to element 3) of the strategy. Treatment controls integrated into and throughout the site usually provide enhanced benefits over the same or similar controls deployed only at the "end of the pipe" where runoff leaves the project site.

3.2 Integration of BMPs into Common Site Features

Many common site features can achieve stormwater management goals by incorporating one or more basic elements, either alone or in combination, depending on site and other conditions. The basic elements include infiltration, retention/detention, biofilters, and structural controls. This section first describes these basic elements, and then describes how these elements can be incorporated into common site features.

Infiltration

Infiltration is the process where water enters the ground and moves downward through the unsaturated soil zone. Infiltration is ideal for management and conservation of runoff because it filters pollutants through the soil and restores natural flows to groundwater and downstream water bodies. See Figure 3-1.

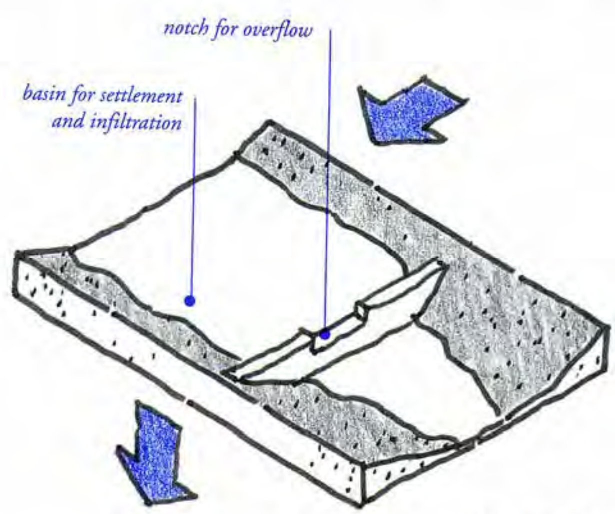


Figure 3-1
Infiltration Basin

The infiltration approach to stormwater management seeks to "preserve and restore the hydrologic cycle." An infiltration stormwater system seeks to infiltrate runoff into the soil by allowing it to flow slowly over permeable surfaces. The slow flow of runoff allows pollutants to settle into the soil where they are naturally mitigated. The reduced volume of runoff that remains takes a long time to reach the outfall, and when it empties into a natural water body or storm sewer, its pollutant load is greatly reduced.

Infiltration basins can be either open or closed. Open infiltration basins, include ponds, swales and other landscape features, are usually vegetated to maintain the porosity of the soil structure and to reduce erosion. Closed infiltration basins can be constructed under the land surface with open graded crushed stone, leaving the surface to be used for parking or other uses. Subsurface closed basins are generally more difficult to maintain and more expensive than open filtration systems, and are used primarily where high land costs demand that the land surface be reclaimed for economic use.

Infiltration systems are often designed to capture the "first flush" storm event and used in combination with a detention basin to control peak hydraulic flows. They effectively remove suspended solids, particulates, bacteria, organics and soluble metals and nutrients through the vehicle of filtration, absorption and microbial decomposition. Groundwater contamination should be considered as a potential adverse effect and should be considered where shallow groundwater is a source of drinking water. In cases where groundwater sources are deep, there is a very low chance of contamination from normal concentrations of typical urban runoff.

Retention and Detention

Retention and detention systems differ from infiltration systems primarily in intent. Detention systems are designed to capture and retain runoff temporarily and release it to receiving waters at predevelopment flow rates. Permanent pools of water are not held between storm events. Pollutants settle out and are removed from the water column through physical processes. See Figure 3-2.

Retention systems capture runoff and retain it between storms as shown in Figure 3-3. Water held in the system is displaced by the next significant rainfall event. Pollutants settle out and are thereby removed from the water column. Because the water remains in the system for a period of time, retention systems benefit from biological and biochemical removal mechanisms provided by aquatic plants and microorganisms. See Figure 3-3.

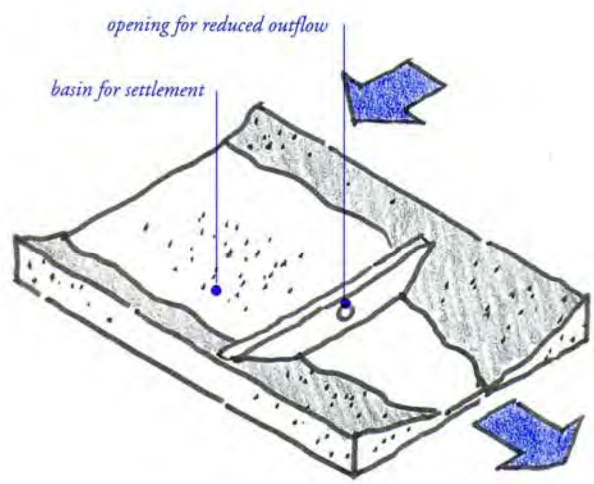


Figure 3-2
Simple Detention System

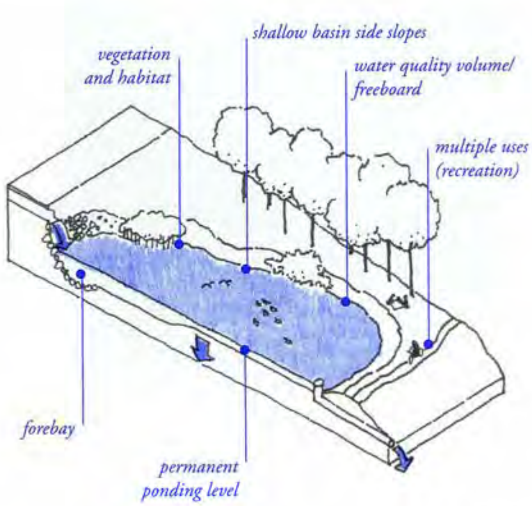


Figure 3-3
Retention System

Retention/detention systems may release runoff slowly enough to reduce downstream peak flows to their pre-development levels, allow fine sediments to settle, and uptake dissolved nutrients in the runoff where wetland vegetation is included.

Bioretention facilities have the added benefit of aesthetic appeal. These systems can be placed in parking lot islands, landscaped areas surrounding buildings, perimeter parking lots, and other open space sections. Placing bioretention facilities on land that city regulations require developers to devote to open space efficiently uses the land. An experienced landscape architect can choose plant species and planting materials that are easy to maintain, aesthetically pleasing, and capable of effectively reducing pollutants in runoff from the site.

Constructed wetland systems retain and release stormwater in a manner that is similar to retention or detention basins. The design mimics natural ecological functions and uses wetland vegetation to filter pollutants. The system needs a permanent water source to function properly and must be engineered to remove coarse sediment, especially construction related sediments, from entering the pond. Stormwater has the potential to negatively affect natural wetland functions and constructed wetlands can be used to buffer sensitive resources.

Biofilters

Biofilters, also known as vegetated swales and filter strips, are vegetated slopes and channels designed and maintained to transport shallow depths of runoff slowly over vegetation. Biofilters are effective if flows are slow and depths are shallow (3% slope max.). The slow movement of runoff through the vegetation provides an opportunity for sediments and particulates to be filtered and degraded through biological activity. In most soils, the biofilter also provides an opportunity for stormwater infiltration, which further removes pollutants and reduces runoff volumes. See Figure 3-4.

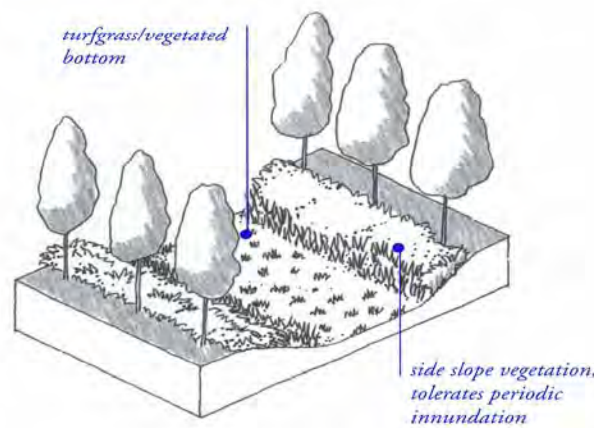


Figure 3-4
Vegetated Swale

Swales intercept both sheet and concentrated flows and convey these flows in a concentrated, vegetation-lined channel. Grass filter strips intercept sheet runoff from the impervious network of streets, parking lots, and rooftops and divert stormwater to a uniformly graded meadow, buffer zone, or small forest. Typically, the vegetated swale and grass strip-planting palette can comprise a wide range of possibilities from dense vegetation to turf grass. Grass strips and vegetated swales can function as pretreatment systems for water entering bioretention systems or other BMPs. If biofilters are to succeed in filtering pollutants from the water column, the planting design must consider the hydrology, soils, and maintenance requirements of the site.

Appropriate plantings not only improve water quality, they provide habitat and aesthetic benefits. Selected plant materials must be able to adapt to variable moisture regimes. Turf grass is acceptable if it can be watered in the dry season, and if it is not inundated for long periods. Species such as willows, dogwoods, sedge, rush, lilies, and bulrush tolerate varying degrees of soil moisture and can provide an attractive plant palette year round.

Structural Controls

Structural controls in the context of this section include a range of measures that prevent pollutants from coming into contact with stormwater. In this context, these measures may be referred to as "structural source controls" meaning that they utilize structural features to prevent pollutant sources and stormwater from coming into contact with one another, thus reducing the opportunity for stormwater to become contaminated. Examples of structural source controls include covers, impermeable surfaces, secondary containment facilities, runoff diversion berms, and diversions to wastewater treatment plants.

3.2.1 Streets

More than any other single element, street design has a powerful impact on stormwater quality. Street and other transportation-related structures typically can comprise between 60 and 70% of the total impervious coverage in urban areas and, unlike rooftops, streets are almost always directly connected to an underground stormwater system.

Recognizing that street design can be the greatest factor in development's impact on stormwater quality, it is important that designers, municipalities and developers employ street standards that reduce impervious land coverage. Directing runoff to biofilters or swales rather than underground storm drains produces a street system that conveys stormwater efficiently while providing both water quality and aesthetic benefits.

On streets where a more urban character is desired, or where a rigid pavement edge is required, curb and gutter systems can be designed to empty into drainage swales. These swales can run parallel to the street, in the parkway between the curb and the sidewalk, or can intersect the street at cross-angles, and run between residences, depending on topography or site planning. Runoff travels along the gutter, but instead of being emptied into a catch basin and underground pipe, multiple openings in the curb direct runoff into surface swales or infiltration/detention basins.

In recent years, new street standards have been gaining acceptance that meets the access requirements of local residential streets while reducing impervious land coverage. These standards create a new class of street that is narrower and more interconnected than the current local street standard, called an "access" street. An access street is at the lowest end of the street hierarchy and is intended only to provide access to a limited number of residences.

Street design is usually mandated by local municipal standards. Officials must consider the scale of the land use as they select stormwater and water quality design solutions. Traffic volume and speeds, bicycle lane design criteria, and residential and business densities influence the willingness of decision makers to permit the narrow streets that include curbless design alternatives.

Emergency service providers often raise objections to reduced street widths. Street designs illustrated here meet national Fire Code standards for emergency access. An interconnected grid system of narrow streets also allows emergency service providers with multiple access routes to compensate for the unlikely possibility that a street may be blocked.

Many municipal street standards mandate 80 to 100% impervious land coverage in the public right-of-way, and are a principal contributor to the environmental degradation caused by development.

A street standard that allows an interconnected system of narrow access streets for residential neighborhoods has the potential to achieve several complimentary environmental and social benefits. A hierarchy of streets sized according to average daily traffic volumes yields a wide variety of benefits: improved safety from lower speeds and volumes, improved aesthetics from street trees and green parkways, reduced impervious land coverage, less heat island effect, and lower development costs. If the reduction in street width is accompanied by a drainage system that allows for infiltration of runoff, the impact of streets on stormwater quality can be greatly mitigated.

There are many examples of narrow streets, from both newly constructed and older communities, which demonstrate the impact of street design on neighborhood character and environmental quality. See Table 3-1.

Table 3-1 Adopted Narrow Street Standards (Typ. Cross-Sections, two-way traffic)

City of Santa Rosa	30 ft wide with parking permitted both sides, <1000 Average Daily Traffic (ADT) 26 – 28 ft with parking permitted one side 20 ft - no parking permitted 20 ft neck downs at intersections
City of Palmdale	28 ft wide with parking permitted both sides
City of San Jose	30 ft wide with parking permitted both sides, <21 Dwelling Units (DU) 34 ft wide with parking permitted both sides, <121 DU
City of Novato	24 ft wide with parking permitted both sides, 2-4 DU 28 ft with parking permitted both sides, 5-15 DU
County of San Mateo	19 ft wide rural pavement cross-section with parking permitted on adjacent gravel shoulders

A comparison of street cross-sections is shown in Figure 3-5.

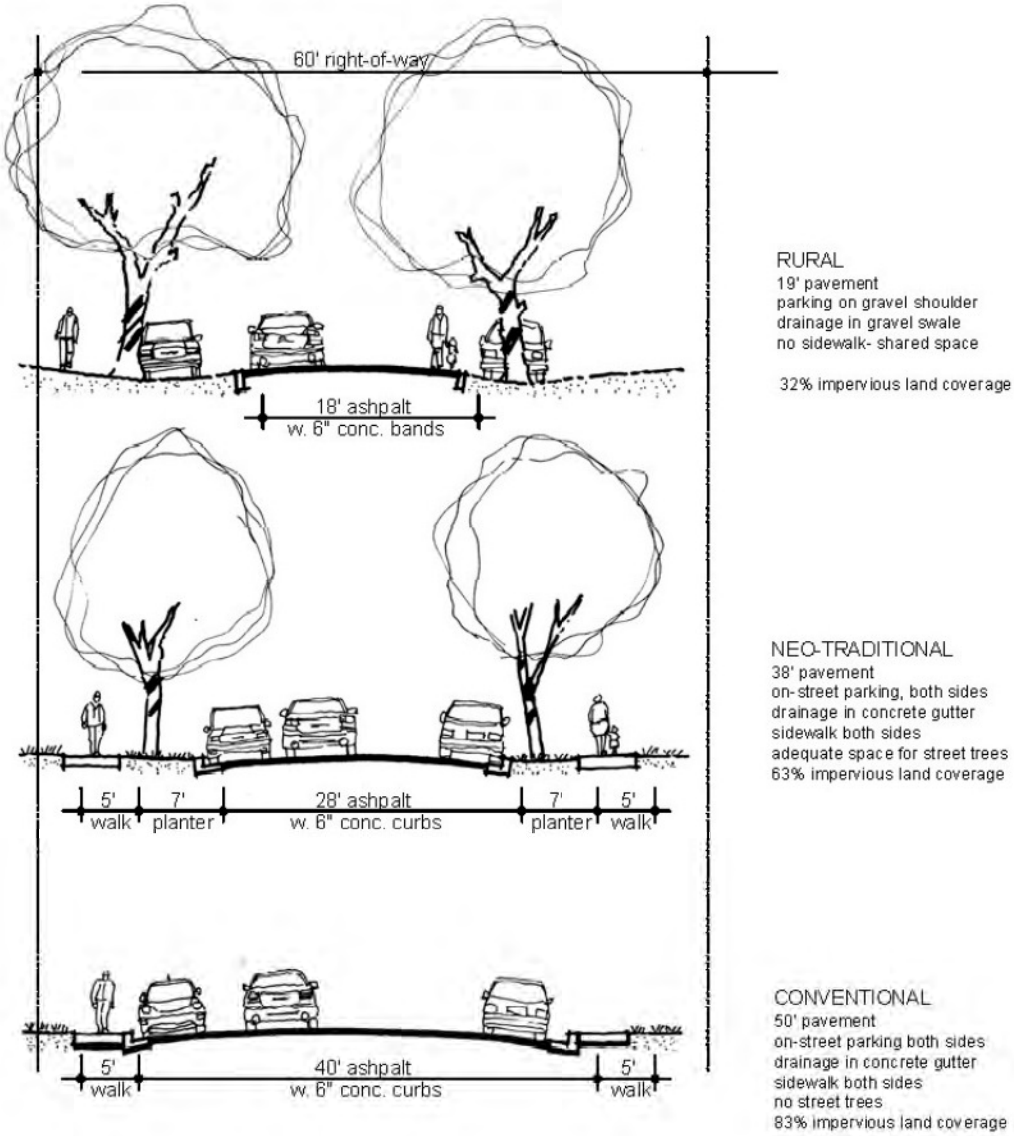


Figure 3-5
Comparison of Street Cross-Sections (two-way traffic, residential access streets)

3.2.2 Parking Lots

In any development, storage space for stationary vehicles can consume many acres of land area, often greater than the area covered by streets or rooftops. In a neighborhood of single-family homes, this parking area is generally located on private driveways or along the street. In higher density residential developments, parking is often consolidated in parking lots.

The space for storage of the automobile, the standard parking stall, occupies only 160 ft^2, but when combined with aisles, driveways, curbs, overhang space, and median islands, a parking lot can require up to 400 ft^2 per vehicle, or nearly one acre per 100 cars. Since parking is usually accommodated on an asphalt or concrete surface with conventional underground storm drain systems, parking lots typically generate a great deal of DCIA.

There are many ways to both reduce the impervious land coverage of parking areas and to filter runoff before it reaches the storm drain system.

Hybrid Parking Lot

Hybrid lots work on the principle that pavement use differs between aisles and stalls. Aisles must be designed for speeds between 10 and 20 mph, and durable enough to support the concentrated traffic of all vehicles using the lot. The stalls, on the other hand, need only be designed for the 2 or 3 mph speed of vehicles maneuvering into place. Most of the time the stalls are in use, vehicles are stationary. Hybrid lots reduce impervious surface coverage in parking areas by differentiating the paving between aisles and stalls, and combining impervious aisles with permeable stalls, as shown in Figure 3-6.

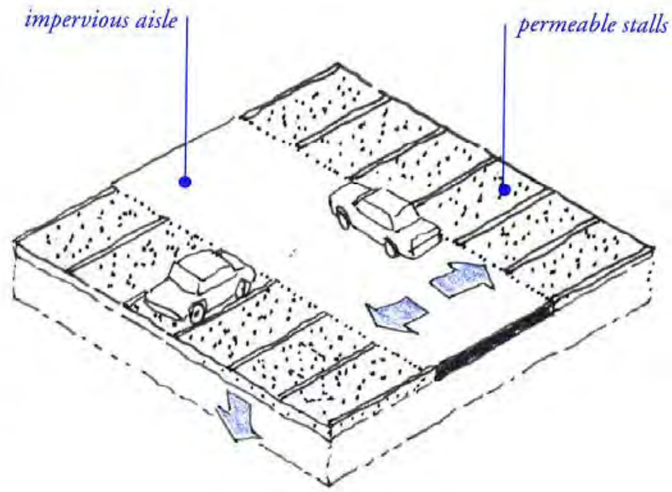


Figure 3-6
Hybrid Parking Lot

If aisles are constructed of a more conventional, impermeable material suitable for heavier vehicle use, such as asphalt, stalls can be constructed of permeable pavement. This can reduce the overall impervious surface coverage of a typical double loaded parking lot by 60% and avoid the need for an underground drainage system.

Permeable stalls can be constructed of a number of materials including pervious concrete, unit pavers such as brick or stone spaced to expose a permeable joint and set on a permeable base, crushed aggregate, porous asphalt, turf block, and cobbles in low traffic areas. Turf blocks and permeable joints are shown in Figures 3-7 and 3-8.

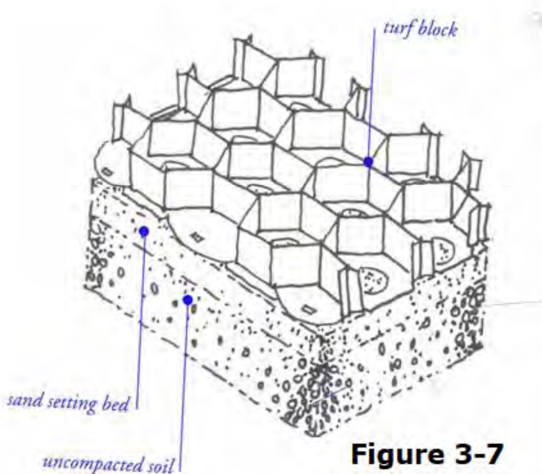


Figure 3-7
Turf Blocks

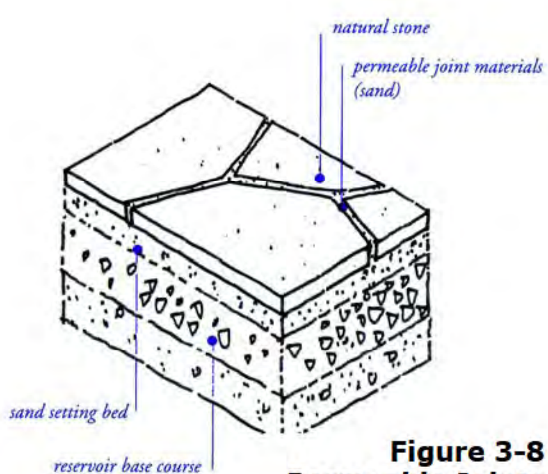


Figure 3-8
Permeable Joints

Parking Grove

A variation on the permeable stall design, a grid of trees and bollards can be used to delineate parking stalls and create a "parking grove." If the bollard and tree grids are spaced approximately 19 ft apart, two vehicles can park between each row of the grid. This 9.5 ft stall spacing is slightly more generous than the standard 8.5 to 9 ft stall, and allows for the added width of the tree trucks and bollards. A benefit of this design is that the parking grove not only shades parked cars, but also presents an attractive open space when cars are absent. Examples of parking groves are shown in Figures 3-9 and 3-10.

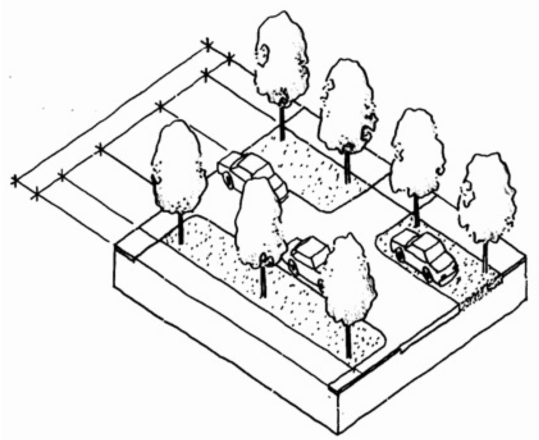


Figure 3-9
Parking Grove

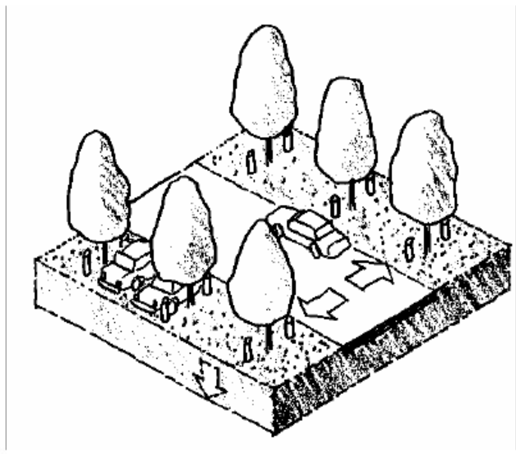


Figure 3-10
Parking Grove

Overflow Parking

Parking lot design is often required to accommodatepeak demand, generating a high proportion of impervious land coverage of very limited usefulness. An alternative is to differentiate between regular and peak parking demands, and to construct the peak parking stalls of a different, more permeable, material. This "overflow parking" area can be made of a turf block, which appears as a green lawn when not occupied by vehicles, or crushed stone or other materials. See Figure 3-11. The same concept can be applied to areas with temporary parking needs, such as emergency access routes, or in residential applications, RV, or trailer parking.

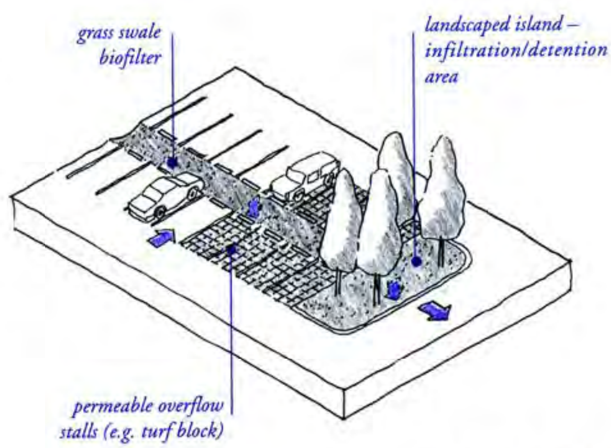


Figure 3-11
Overflows Parking

Porous Pavement Recharge Bed

In some cases, parking lots can be designed to perform more complex stormwater management functions. Constructing a stone-filled reservoir below the pavement surface and directing runoff underground by means of perforated distribution pipes can achieve subsurface stormwater storage and infiltration as shown in Figure 3-12. Subsurface infiltration basins eliminate the possibilities of mud, mosquitoes and safety hazards sometimes perceived to be associated with ephemeral surface drainage. They also can provide for storage of large volumes of runoff, and can be incorporated with roof runoff collection systems.

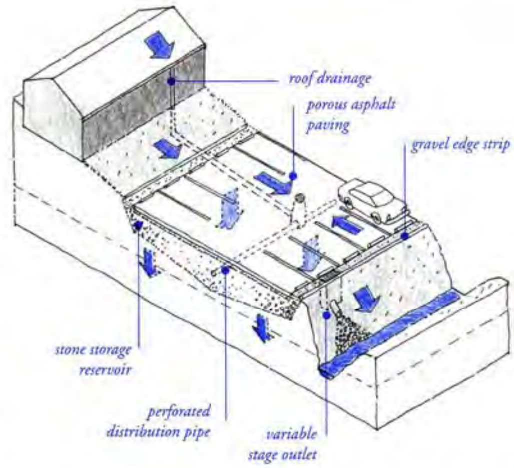


Figure 3-12
Porous Pavement Recharge Bed

3.2.3 Driveways

Driveways can comprise up to 40% of the total transportation network in a conventional development, with streets, turn-arounds, and sidewalks comprising the remaining 60%.

Driveway length is generally determined by garage setback requirements, and width is usually mandated by municipal codes and ordinances. If garages are setback from the street, long driveways are required, unless a rear alley system is included to provide garage access. If parking for two vehicles side by side is required, a 20 ft minimum width is required. Thus, if a 20 ft setback and a two-car-wide driveway are required, a minimum of 400 ft^2 of driveway will result, or 4% of a typical 10,000 ft^2 residential lot. If the house itself is compact, and the driveway is long, wide, and paved with an impervious material such as asphalt or concrete, it can become the largest component of impervious land coverage on the lot.

Municipalities can reduce the area dedicated to driveways by allowing for tandem parking (one vehicle in front of another on a narrow driveway). In addition, if shared driveways are permitted, then two or more garages can be accessed by a single driveway, further reducing required land area. Rear alley access to the garage can reduce driveway length, but overall impervious surface coverage may not be reduced if the alleys are paved with impervious materials and the access streets remain designed to conventional municipal standards.

Alternative solutions that work to reduce the impact of water quality problems associated with impervious land coverage on city streets also work on driveways. Sloping the driveway so that it drains onto an adjacent turf or groundcover area prevents driveways from draining directly to storm drain systems. This concept is shown in Figures 3-13 and 3-14. Use of turf-block or unit pavers on sand creates attractive, low maintenance, permeable driveways that filter stormwater. See Figure 3-15. Crushed aggregate can serve as a relatively smooth pavement with minimal maintenance as shown in Figure 3-16. Paving only under wheels (Figure 3-17) is a viable, inexpensive design if the driveway is straight between the garage and the street, and repaving temporary parking areas with permeable unit pavers such as brick or stone can significantly reduce the percentage of impervious area devoted to the driveway.

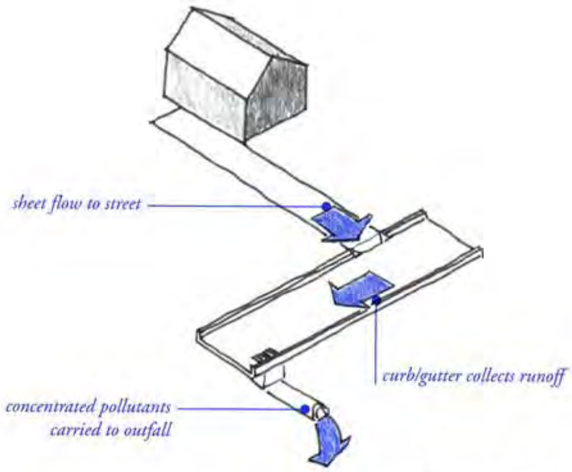


Figure 3-13
Traditional Design
Drains Flow Directly to Storm Drain

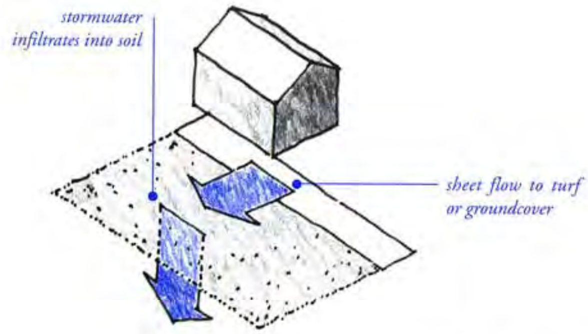


Figure 3-14
Alternative Solution
Slopes Flow to Groundcover

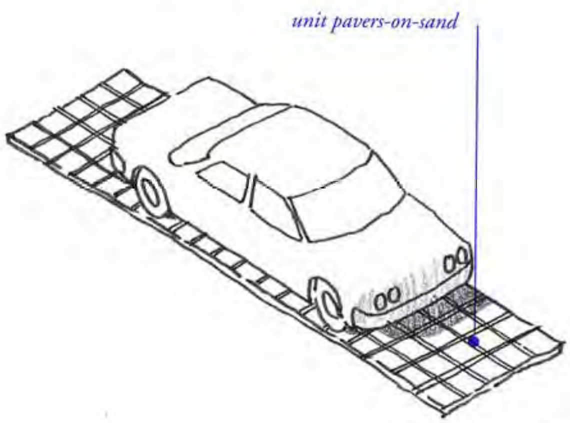


Figure 3-15
Unit Pavers

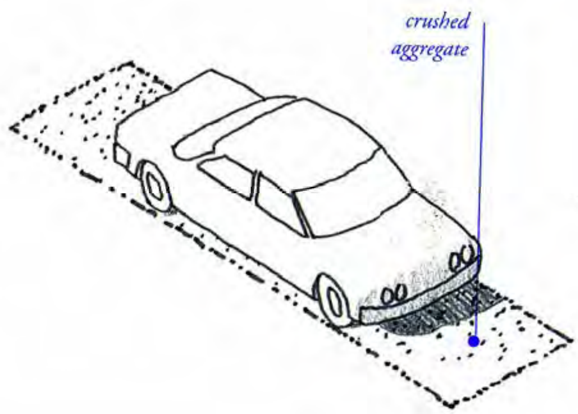


Figure 3-16
Crushed Aggregate

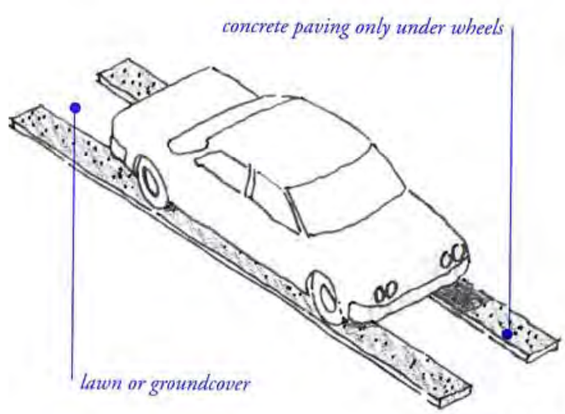


Figure 3-17
Paving Only Under Wheels

3.2.4 Landscape and Open Space

In the natural landscape, most soils infiltrate a high percentage of rainwater through a complex web of organic and biological activities that build soil porosity and permeability. Roots reach into the soil and separate particles of clay, insects excavate voids in the soil mass, roots decay leaving networks of macro pores, leaves fall and form a mulch over the soil surface, and earthworms burrow and ingest organic detritus to create richer, more porous soil. These are just a few examples of the natural processes that occur within the soil.

Maintenance of a healthy soil structure through the practice of retaining or restoring native soils where possible and using soil amendments where appropriate can improve the land's ability to filter and slowly release stormwater into drainage networks. Construction practices such as decreasing soil compaction, storing topsoil on-site for use after construction, and chipping wood for mulch as it is cleared for the land can improve soil quality and help maintain healthy watersheds. Practices that reduce erosion and help retain water on-site include incorporating organic amendments into disturbed soils after construction, retaining native vegetation, and covering soil during revegetation.

Subtle changes in grading can also improve infiltration. Landscape surfaces are conventionally graded to have a slight convex slope. This causes water to run off a central high point into a surrounding drainage system, creating increased runoff. If a landscape surface is graded to have a slightly concave slope, it will hold water. The infiltration value of concave vegetated surfaces is greater in permeable soils. Soils of heavy clay or underlain with hardpan provide less infiltration value. In these cases, concave vegetated surfaces must be designed as retention/detention basins, with proper outlets or under drains to an interconnected system.

Multiple Small Basins

Biofilters, infiltration, retention/detention basins are the basic elements of a landscape designed for stormwater management. The challenge for designers is to integrate these elements creatively and attractively in the landscape – either within a conventional landscape aesthetic or by presenting a different landscape image that emphasizes the role of water and drainage.

Multiple small basins can provide a great deal of water storage and infiltration capacity. These small basins can fit into the parkway planting strip or shoulders of street rights-of-way. If connected by culverts under walks and driveways, they can create a continuous linear infiltration system. Infiltration and retention/detention basins can be placed under wood decks, in parking lot planter islands, and at roof downspouts. Outdoor patios or seating areas can be sunken a few steps, paved with a permeable pavement such as flagstone or gravel, and designed to hold a few inches of water collected from surrounding rooftops or paved areas for a few hours after a rain.

All of these are examples of small basins that can store water for a brief period, allowing it to infiltrate into the soil, slowing its release into the drainage network, and filtering pollutants. An ordinary lawn can be designed to hold a few inches of water for a few hours after a storm, attracting birds and creating a landscape of diversity. Grass/vegetated swales can be integrated with landscaping, providing an attractive, low maintenance, linear biofilter. Extended detention (dry ponds) store water during storms, holding runoff to predevelopment levels. Pollutants settle and are removed from the water column before discharging to streams. Wet ponds serve a similar purpose and can increase property values by providing a significant aesthetic, and passive recreation opportunity.

Plant species selection is critical for proper functioning of infiltration areas. Proper selection of plant materials can improve the infiltration potential of landscape areas. Deep-rooted plants help to build soil porosity. Plant leaf-surface area helps to collect rainwater before it lands on the soil, especially in light rains, increasing the overall water-holding potential of the landscape.

A large number of plant species will survive moist soils or periodic inundation. These plants provide a wide range of choices for planted infiltration/detention basins and drainage swales. Most inundated plants have a higher survival potential on well-drained alluvial soils than on fine textured shallow soils or clays.

Maintenance Needs for Stormwater Systems

All landscape treatments require maintenance. Landscapes designed to perform stormwater management functions are not necessarily more maintenance intensive than highly manicured conventional landscapes. A concave lawn requires the same mowing, fertilizing, and weeding as a convex one and often less irrigation because more rain is filtered into the underlying soil. Sometimes infiltration basins may require a different kind of maintenance than conventionally practiced.

Typical maintenance activities include periodic inspection of surface drainage systems to ensure clear flow lines, repair of eroded surfaces, adjustment or repair of drainage structures, soil cultivation or aeration, care of plant materials, replacement of dead plants, replenishment of mulch cover, irrigation, fertilizing, pruning and mowing. In addition, dead or stressed vegetation may indicate chemical dumping. Careful observation should be made of these areas to determine if such a problem exists.

Landscape maintenance can have a significant impact on soil permeability and its ability to support plant growth. Most plants concentrate the majority of their small absorbing roots in the upper 6 in. of the soil surface if a mulch or forest litter protects the surface. If the soil is exposed or bare, it can become so hot that surface roots will not grow in the upper 8 to 10 in. The common practice of removing all leaf litter and detritus with leaf blowers creates a hard-crusted soil surface of low permeability and high heat conduction. Proper mulching of the soil surface improves water retention and infiltration, while protecting the surface root zone from temperature extremes.

In addition to impacting permeability, landscape maintenance practices can have adverse effects on water quality. Because commonly used fertilizers and herbicides are a source of organic compounds, it is important to keep these practices to a minimum, and prevent overwatering.

When well maintained and designed, landscaped concave surfaces, infiltration basins, swales and bioretention areas can add aesthetic value while providing the framework for environmentally sound, comprehensive stormwater management systems.

Street Trees

Trees improve water quality by intercepting and storing rainfall on leaves and branch surfaces, thereby reducing runoff volumes and delaying the onset of peak flows. A single street tree can have a total leaf surface area of several hundred to several thousand ft^2, depending on species and size. This aboveground surface area created by trees and other plants greatly contributes to the water holding capacity of the land. They attenuate conveyance by increasing the soil's capacity to filter rainwater and reduce overland flow rates. By diminishing the impact of raindrops on un-vegetated soil, trees reduce soil erosion. Street trees also have the ability to reduce ambient temperature of stormwater runoff and absorb surface water pollutants.

When using street trees to achieve stormwater management goals, it is important to use tree species with wide canopies. Street tree design criteria should specify species expected to attain 20 to 30 ft canopies at maturity. Planter strips with adequate width and depth of soil volume are necessary to ensure tree vitality and reduce future maintenance. Structural soils also provide rooting space for large trees and can be specified along narrow planter strips and underneath sidewalks to enable continuous belowground soil and root connections.

3.2.5 Outdoor Work Areas

The site design and landscape details listed in previous sections are appropriate for uses where low concentrations of pollutants can be mitigated through infiltration, retention, and detention. Often in commercial and industrial sites, there are outdoor work areas in which a higher concentration of pollutants exists, and thus a higher potential of pollutants infiltrating the soil. These work areas often involve automobiles, equipment machinery, or other commercial and industrial uses, and require special consideration.

Outdoor work areas are usually isolated elements in a larger development. Infiltration and detention strategies are still appropriate for and can be applied to other areas of the site, such as parking lots, landscape areas, employee use areas, and bicycle path. It is only the outdoor work area within the development – such as the loading dock, fueling area, or equipment wash area – that requires a different drainage approach. This drainage approach is often precisely the opposite from the infiltration/detention strategy – in other words, collect and convey.

In these outdoor work areas, infiltration is discouraged and runoff is often routed directly to the sanitary sewer, not the storm drain. Because this runoff is being added to the loads normally received by the water treatment plants (publicly owned treatment works – POTWs), it raises several concerns that must be addressed in the planning and design stage. These include:

- Higher flows that could exceed the sewer system capacity
- Catastrophic spills that may cause harm to POTW operation
- A potential increase in pollutants

These concerns can be addressed at policy, management, and site planning levels.

Policy

Piping runoff and process water from outdoor work areas directly to the sanitary sewer for treatment by a downstream POTW displaces the problem of reducing stormwater pollution. Municipal stormwater programs and/or private developers can work with the local POTW to develop solutions that minimize effects on the treatment facility. It should be noted that many POTWs have traditionally prohibited the discharge of stormwater to their systems. However, these prohibitions are being reviewed in light of the benefits possible from such diversions.

Management

Commercial and industrial sites that host special activities need to implement a pollution prevention program minimizing hazardous material use and waste. For example, if restaurant grease traps are directly connected to the sanitary sewer, proper management programs can mitigate the amount of grease that escapes from the trap, clogging sewer systems and causing overflows or damage to downstream systems.

Site Planning

Outdoor work areas can be designed in particular ways to reduce their impacts on both stormwater quality and sewage treatment plants.

- Create an impermeable surface such as concrete or asphalt, or a prefabricated metal drip pan, depending on the use.
- Cover the area with a roof. This prevents rain from falling on the work area and becoming polluted runoff.
- Berm or mound around the perimeter of the area to prevent water from adjacent areas to flow on to the surface of the work area.
- Directly connect runoff. Unlike other areas, runoff from these work areas is directly connected to the sanitary sewer or other specialized containment systems. This allows the more highly concentrated pollutants from these areas to receive special treatment that removes particular constituents. Approval for this connection must be obtained from the appropriate sanitary sewer agency.
- Locate the work area away from storm drains or catch basins. If the work area is adjacent to, or directly upstream from a storm drain or landscape drainage feature (e.g., bioswales), debris or liquids from the work area can migrate into the stormwater system.
- Plan the work area to prevent run-on. This can be accomplished by raising the work area or by diverting run-on around the work area.

These design elements are general considerations for work areas. In designing any outdoor work area, evaluate local ordinances affecting the type of work area, as many local jurisdictions have specific requirements.

Some activities are common to many commercial and industrial sites. These include garbage and recycling, maintenance and storage, and loading. These activities can have a significant negative impact on stormwater quality, and require special attention to the siting and design of the activity area.

3.2.6 Maintenance and Storage Areas

To reduce the possibility of contact with stormwater runoff, maintenance and storage areas can be sited away from drainage paths and waterways, and covered. Implementing a regular maintenance plan for sweeping, litter control, and spill cleanup also helps prevent stormwater pollution.

Specifying impermeable surfaces for vehicle and equipment maintenance areas will reduce the chance of pollutant infiltration. A concrete surface will usually last much longer than an asphalt one, as vehicle fluids can either dissolve asphalt or be absorbed by the asphalt and released later. See Figure 3-18.

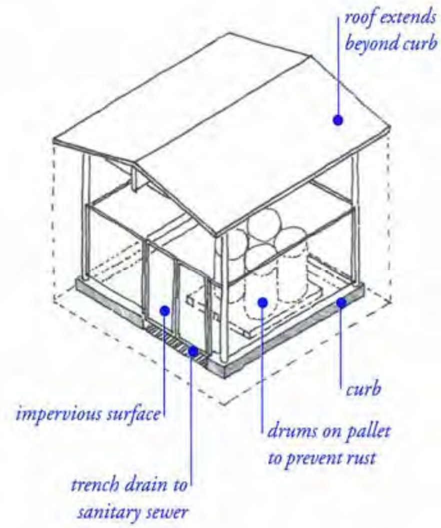


Figure 3-18
Material Storage

3.2.7 Vehicle and Equipment Washing Areas

It is generally advisable to cover areas used for regular washing of vehicles, trucks, or equipment, surround them with a perimeter berm, and clearly mark them as a designated washing area. Sumps or drain lines can be installed to collect wash water, which may be treated for reuse or recycling, or for discharge to the sanitary sewer. The POTW may require some form of pretreatment, such as a trap, for these areas.

Fueling and maintenance activities must be isolated from the vehicle washing facilities. These activities have specific requirements, described later in this section.

Storage of bulk materials, fuels, oils, solvents, other chemicals, and process equipment should be accommodated on an impervious surface covered with a roof. To reduce the chances of corrosion, materials should not be stored directly on the ground, but supported by a wire mesh or other flooring above the impervious pavement. In uncovered areas, drums or other containers can be stored at a slight angle to prevent ponding of rainwater from rusting the lids. Liquid containers should be stored in a designated impervious area that is roofed, fenced within a berm, to prevent spills from flowing into the storm drain.

If hazardous materials are being used or stored, additional specific local, state, or federal requirements may apply.

3.2.8 Loading Area

Loading areas and docks can be designed with a roof or overhang, and a surrounding curb or berm. See Figure 3-19. The area should be graded to direct flow toward an inlet with a shutoff valve or dead-end sump. The sump must be designed with enough capacity to hold a spill while the valve is closed. If the sump has a valve, it must be kept in the closed position and require an action to open it. All sumps must have a sealed bottom so they cannot infiltrate water. Contaminated accumulated waste and liquid must not be discharged to a storm drain and may be discharged to the sanitary sewer only with the POTW's permission. If the waste is not approved for discharge to the sanitary sewer, it must be conveyed to a hazardous waste (or other offsite disposal) facility, and may require pretreatment. Some specific uses have unique requirements.

3.2.9 Trash Storage Areas

Areas designated for trash storage can be covered to protect containers from rainfall. Where covering the trash storage area is not feasible, the area can be protected from run on using grading and berms, and connected to the sanitary sewer to prevent leaks from leaving the designated trash storage area enclosure.

3.2.10 Wash Areas

Areas designated for washing of floor mats, containers, exhaust filters, and similar items can be covered and enclosed to protect the area from rainfall and from overspray leaving the area. These areas can also be connected to the sanitary sewer to prevent wash waters from leaving the designated enclosures. A benefit of covering and enclosing these areas is that vectors may be reduced and aesthetics of the area improved.

3.2.11 Fueling Areas

In all vehicle and equipment fueling areas, plans must be developed for cleaning near fuel dispensers, emergency spill cleanup, and routine inspections to prevent leaks and ensure properly functioning equipment.

If the fueling activities are minor, fueling can be performed in a designated, covered, and bermed area that will not allow run-on of stormwater or runoff of spills.

Retail gasoline outlets and vehicle fueling areas have specific design guidelines. These are described in a Best Management Practice Guide for retail gasoline outlets developed by the California Stormwater Quality Task Force, in cooperation with major gasoline corporations. The practice guide addresses standards for existing, new, or substantially remodeled facilities. In addition, some municipal stormwater permits require RGOs to provide appropriate runoff treatment.

Fuel dispensing areas are defined as extending 6.5 ft from the corner of each fuel dispenser or the length at which the hose and nozzle assembly may be operated plus 1 ft, whichever is less. These areas must be paved with smooth impervious surfaces, such as Portland cement concrete, with a 2-4% slope to prevent ponding, and must be covered. The cover must not drain onto the work area. The rest of the site must separate the fuel dispensing area by a grade break that prevents run-on of stormwater.

Within the gas station, the outdoor trash receptacle area (garbage and recycling), and the air/water supply area must be paved and graded to prevent stormwater run-on. Trash receptacles should be covered.

Design Objectives

- ☑ Maximize Infiltration
- ☑ Provide Retention
- ☑ Slow Runoff
- ☑ Minimize Impervious Land Coverage
- Prohibit Dumping of Improper Materials
- Contain Pollutants
- Collect and Convey

Description

Each project site possesses unique topographic, hydrologic, and vegetative features, some of which are more suitable for development than others. Integrating and incorporating appropriate landscape planning methodologies into the project design is the most effective action that can be done to minimize surface and groundwater contamination from stormwater.

Approach

Landscape planning should couple consideration of land suitability for urban uses with consideration of community goals and projected growth. Project plan designs should conserve natural areas to the extent possible, maximize natural water storage and infiltration opportunities, and protect slopes and channels.

Suitable Applications

Appropriate applications include residential, commercial and industrial areas planned for development or redevelopment.

Design Considerations

Design requirements for site design and landscapes planning should conform to applicable standards and specifications of agencies with jurisdiction and be consistent with applicable General Plan and Local Area Plan policies.

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Designing New Installations

Begin the development of a plan for the landscape unit with attention to the following general principles:

- Formulate the plan on the basis of clearly articulated community goals. Carefully identify conflicts and choices between retaining and protecting desired resources and community growth.

- Map and assess land suitability for urban uses. Include the following landscape features in the assessment: wooded land, open unwooded land, steep slopes, erosion-prone soils, foundation suitability, soil suitability for waste disposal, aquifers, aquifer recharge areas, wetlands, floodplains, surface waters, agricultural lands, and various categories of urban land use. When appropriate, the assessment can highlight outstanding local or regional resources that the community determines should be protected (e.g., a scenic area, recreational area, threatened species habitat, farmland, fish run). Mapping and assessment should recognize not only these resources but also additional areas needed for their sustenance.

Project plan designs should conserve natural areas to the extent possible, maximize natural water storage and infiltration opportunities, and protect slopes and channels.

Conserve Natural Areas during Landscape Planning

If applicable, the following items are required and must be implemented in the site layout during the subdivision design and approval process, consistent with applicable General Plan and Local Area Plan policies:

- Cluster development on least-sensitive portions of a site while leaving the remaining land in a natural undisturbed condition.

- Limit clearing and grading of native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection.

- Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought tolerant plants.

- Promote natural vegetation by using parking lot islands and other landscaped areas.

- Preserve riparian areas and wetlands.

Maximize Natural Water Storage and Infiltration Opportunities Within the Landscape Unit

- Promote the conservation of forest cover. Building on land that is already deforested affects basin hydrology to a lesser extent than converting forested land. Loss of forest cover reduces interception storage, detention in the organic forest floor layer, and water losses by evapotranspiration, resulting in large peak runoff increases and either their negative effects or the expense of countering them with structural solutions.

- Maintain natural storage reservoirs and drainage corridors, including depressions, areas of permeable soils, swales, and intermittent streams. Develop and implement policies and regulations to discourage the clearing, filling, and channelization of these features. Utilize them in drainage networks in preference to pipes, culverts, and engineered ditches.

- Evaluating infiltration opportunities by referring to the stormwater management manual for the jurisdiction and pay particular attention to the selection criteria for avoiding groundwater contamination, poor soils, and hydrogeological conditions that cause these facilities to fail. If necessary, locate developments with large amounts of impervious surfaces or a potential to produce relatively contaminated runoff away from groundwater recharge areas.

Protection of Slopes and Channels during Landscape Design

- Convey runoff safely from the tops of slopes.
- Avoid disturbing steep or unstable slopes.
- Avoid disturbing natural channels.
- Stabilize disturbed slopes as quickly as possible.
- Vegetate slopes with native or drought tolerant vegetation.
- Control and treat flows in landscaping and/or other controls prior to reaching existing natural drainage systems.
- Stabilize temporary and permanent channel crossings as quickly as possible, and ensure that increases in run-off velocity and frequency caused by the project do not erode the channel.
- Install energy dissipaters, such as riprap, at the outlets of new storm drains, culverts, conduits, or channels that enter unlined channels in accordance with applicable specifications to minimize erosion. Energy dissipaters shall be installed in such a way as to minimize impacts to receiving waters.
- Line on-site conveyance channels where appropriate, to reduce erosion caused by increased flow velocity due to increases in tributary impervious area. The first choice for linings should be grass or some other vegetative surface, since these materials not only reduce runoff velocities, but also provide water quality benefits from filtration and infiltration. If velocities in the channel are high enough to erode grass or other vegetative linings, riprap, concrete, soil cement, or geo-grid stabilization are other alternatives.
- Consider other design principles that are comparable and equally effective.

Redeveloping Existing Installations

Various jurisdictional stormwater management and mitigation plans (SUSMP, WQMP, etc.) define “redevelopment” in terms of amounts of additional impervious area, increases in gross floor area and/or exterior construction, and land disturbing activities with structural or impervious surfaces. The definition of “ redevelopment” must be consulted to determine whether or not the requirements for new development apply to areas intended for redevelopment. If the definition applies, the steps outlined under “designing new installations” above should be followed.

Redevelopment may present significant opportunity to add features which had not previously been implemented. Examples include incorporation of depressions, areas of permeable soils, and swales in newly redeveloped areas. While some site constraints may exist due to the status of already existing infrastructure, opportunities should not be missed to maximize infiltration, slow runoff, reduce impervious areas, disconnect directly connected impervious areas.

Other Resources

A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.

Stormwater Management Manual for Western Washington, Washington State Department of Ecology, August 2001.

Model Standard Urban Storm Water Mitigation Plan (SUSMP) for San Diego County, Port of San Diego, and Cities in San Diego County, February 14, 2002.

Model Water Quality Management Plan (WQMP) for County of Orange, Orange County Flood Control District, and the Incorporated Cities of Orange County, Draft February 2003.

Ventura Countywide Technical Guidance Manual for Stormwater Quality Control Measures, July 2002.

Design Considerations

- Tributary Area
- Area Required
- Slope
- Water Availability

Description

Vegetated swales are open, shallow channels with vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. They are designed to treat runoff through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils. Swales can be natural or manmade. They trap particulate pollutants (suspended solids and trace metals), promote infiltration, and reduce the flow velocity of stormwater runoff. Vegetated swales can serve as part of a stormwater drainage system and can replace curbs, gutters and storm sewer systems.

California Experience

Caltrans constructed and monitored six vegetated swales in southern California. These swales were generally effective in reducing the volume and mass of pollutants in runoff. Even in the areas where the annual rainfall was only about 10 inches/yr, the vegetation did not require additional irrigation. One factor that strongly affected performance was the presence of large numbers of gophers at most of the sites. The gophers created earthen mounds, destroyed vegetation, and generally reduced the effectiveness of the controls for TSS reduction.

Advantages

- If properly designed, vegetated, and operated, swales can serve as an aesthetic, potentially inexpensive urban development or roadway drainage conveyance measure with significant collateral water quality benefits.

Targeted Constituents

☑	Sediment	▲
☑	Nutrients	●
☑	Trash	●
☑	Metals	▲
☑	Bacteria	●
☑	Oil and Grease	▲
☑	Organics	▲

Legend ***(Removal Effectiveness)***

● Low ■ High

▲ Medium

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- Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible.

Limitations

- Can be difficult to avoid channelization.
- May not be appropriate for industrial sites or locations where spills may occur
- Grassed swales cannot treat a very large drainage area. Large areas may be divided and treated using multiple swales.
- A thick vegetative cover is needed for these practices to function properly.
- They are impractical in areas with steep topography.
- They are not effective and may even erode when flow velocities are high, if the grass cover is not properly maintained.
- In some places, their use is restricted by law: many local municipalities require curb and gutter systems in residential areas.
- Swales are mores susceptible to failure if not properly maintained than other treatment BMPs.

Design and Sizing Guidelines

- Flow rate based design determined by local requirements or sized so that 85% of the annual runoff volume is discharged at less than the design rainfall intensity.
- Swale should be designed so that the water level does not exceed 2/3rds the height of the grass or 4 inches, which ever is less, at the design treatment rate.
- Longitudinal slopes should not exceed 2.5%
- Trapezoidal channels are normally recommended but other configurations, such as parabolic, can also provide substantial water quality improvement and may be easier to mow than designs with sharp breaks in slope.
- Swales constructed in cut are preferred, or in fill areas that are far enough from an adjacent slope to minimize the potential for gopher damage. Do not use side slopes constructed of fill, which are prone to structural damage by gophers and other burrowing animals.
- A diverse selection of low growing, plants that thrive under the specific site, climatic, and watering conditions should be specified. Vegetation whose growing season corresponds to the wet season are preferred. Drought tolerant vegetation should be considered especially for swales that are not part of a regularly irrigated landscaped area.
- The width of the swale should be determined using Manning's Equation using a value of 0.25 for Manning's n.

Construction/Inspection Considerations

- Include directions in the specifications for use of appropriate fertilizer and soil amendments based on soil properties determined through testing and compared to the needs of the vegetation requirements.

- Install swales at the time of the year when there is a reasonable chance of successful establishment without irrigation; however, it is recognized that rainfall in a given year may not be sufficient and temporary irrigation may be used.

- If sod tiles must be used, they should be placed so that there are no gaps between the tiles; stagger the ends of the tiles to prevent the formation of channels along the swale or strip.

- Use a roller on the sod to ensure that no air pockets form between the sod and the soil.

- Where seeds are used, erosion controls will be necessary to protect seeds for at least 75 days after the first rainfall of the season.

Performance

The literature suggests that vegetated swales represent a practical and potentially effective technique for controlling urban runoff quality. While limited quantitative performance data exists for vegetated swales, it is known that check dams, slight slopes, permeable soils, dense grass cover, increased contact time, and small storm events all contribute to successful pollutant removal by the swale system. Factors decreasing the effectiveness of swales include compacted soils, short runoff contact time, large storm events, frozen ground, short grass heights, steep slopes, and high runoff velocities and discharge rates.

Conventional vegetated swale designs have achieved mixed results in removing particulate pollutants. A study performed by the Nationwide Urban Runoff Program (NURP) monitored three grass swales in the Washington, D.C., area and found no significant improvement in urban runoff quality for the pollutants analyzed. However, the weak performance of these swales was attributed to the high flow velocities in the swales, soil compaction, steep slopes, and short grass height.

Another project in Durham, NC, monitored the performance of a carefully designed artificial swale that received runoff from a commercial parking lot. The project tracked 11 storms and concluded that particulate concentrations of heavy metals (Cu, Pb, Zn, and Cd) were reduced by approximately 50 percent. However, the swale proved largely ineffective for removing soluble nutrients.

The effectiveness of vegetated swales can be enhanced by adding check dams at approximately 17 meter (50 foot) increments along their length (See Figure 1). These dams maximize the retention time within the swale, decrease flow velocities, and promote particulate settling. Finally, the incorporation of vegetated filter strips parallel to the top of the channel banks can help to treat sheet flows entering the swale.

Only 9 studies have been conducted on all grassed channels designed for water quality (Table 1). The data suggest relatively high removal rates for some pollutants, but negative removals for some bacteria, and fair performance for phosphorus.

Table 1 Grassed swale pollutant removal efficiency data							
Removal Efficiencies (% Removal)							
Study	**TSS**	**TP**	**TN**	**NO_3**	**Metals**	**Bacteria**	**Type**
Caltrans 2002	77	8	67	66	83-90	-33	dry swales
Goldberg 1993	67.8	4.5	-	31.4	42–62	-100	grassed channel
Seattle Metro and Washington Department of Ecology 1992	60	45	-	-25	2–16	-25	grassed channel
Seattle Metro and Washington Department of Ecology, 1992	83	29	-	-25	46–73	-25	grassed channel
Wang et al., 1981	80	-	-	-	70–80	-	dry swale
Dorman et al., 1989	98	18	-	45	37–81	-	dry swale
Harper, 1988	87	83	84	80	88–90	-	dry swale
Kercher et al., 1983	99	99	99	99	99	-	dry swale
Harper, 1988.	81	17	40	52	37–69	-	wet swale
Koon, 1995	67	39	-	9	-35 to 6	-	wet swale

While it is difficult to distinguish between different designs based on the small amount of available data, grassed channels generally have poorer removal rates than wet and dry swales, although some swales appear to export soluble phosphorus (Harper, 1988; Koon, 1995). It is not clear why swales export bacteria. One explanation is that bacteria thrive in the warm swale soils.

Siting Criteria

The suitability of a swale at a site will depend on land use, size of the area serviced, soil type, slope, imperviousness of the contributing watershed, and dimensions and slope of the swale system (Schueler et al., 1992). In general, swales can be used to serve areas of less than 10 acres, with slopes no greater than 5 %. Use of natural topographic lows is encouraged and natural drainage courses should be regarded as significant local resources to be kept in use (Young et al., 1996).

Selection Criteria (NCTCOG, 1993)

- Comparable performance to wet basins
- Limited to treating a few acres
- Availability of water during dry periods to maintain vegetation
- Sufficient available land area

Research in the Austin area indicates that vegetated controls are effective at removing pollutants even when dormant. Therefore, irrigation is not required to maintain growth during dry periods, but may be necessary only to prevent the vegetation from dying.

The topography of the site should permit the design of a channel with appropriate slope and cross-sectional area. Site topography may also dictate a need for additional structural controls. Recommendations for longitudinal slopes range between 2 and 6 percent. Flatter slopes can be used, if sufficient to provide adequate conveyance. Steep slopes increase flow velocity, decrease detention time, and may require energy dissipating and grade check. Steep slopes also can be managed using a series of check dams to terrace the swale and reduce the slope to within acceptable limits. The use of check dams with swales also promotes infiltration.

Additional Design Guidelines

Most of the design guidelines adopted for swale design specify a minimum hydraulic residence time of 9 minutes. This criterion is based on the results of a single study conducted in Seattle, Washington (Seattle Metro and Washington Department of Ecology, 1992), and is not well supported. Analysis of the data collected in that study indicates that pollutant removal at a residence time of 5 minutes was not significantly different, although there is more variability in that data. Therefore, additional research in the design criteria for swales is needed. Substantial pollutant removal has also been observed for vegetated controls designed solely for conveyance (Barrett et al, 1998); consequently, some flexibility in the design is warranted.

Many design guidelines recommend that grass be frequently mowed to maintain dense coverage near the ground surface. Recent research (Colwell et al., 2000) has shown mowing frequency or grass height has little or no effect on pollutant removal.

Summary of Design Recommendations

1) The swale should have a length that provides a minimum hydraulic residence time of at least 10 minutes. The maximum bottom width should not exceed 10 feet unless a dividing berm is provided. The depth of flow should not exceed 2/3rds the height of the grass at the peak of the water quality design storm intensity. The channel slope should not exceed 2.5%.

2) A design grass height of 6 inches is recommended.

3) Regardless of the recommended detention time, the swale should be not less than 100 feet in length.

4) The width of the swale should be determined using Manning's Equation, at the peak of the design storm, using a Manning's n of 0.25.

5) The swale can be sized as both a treatment facility for the design storm and as a conveyance system to pass the peak hydraulic flows of the 100-year storm if it is located "on-line." The side slopes should be no steeper than 3:1 (H:V).

6) Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible. If flow is to be introduced through curb cuts, place pavement slightly above the elevation of the vegetated areas. Curb cuts should be at least 12 inches wide to prevent clogging.

7) Swales must be vegetated in order to provide adequate treatment of runoff. It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing, water-resistant grasses. If possible, divert runoff (other than necessary irrigation) during the period of vegetation

establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.

Maintenance

The useful life of a vegetated swale system is directly proportional to its maintenance frequency. If properly designed and regularly maintained, vegetated swales can last indefinitely. The maintenance objectives for vegetated swale systems include keeping up the hydraulic and removal efficiency of the channel and maintaining a dense, healthy grass cover.

Maintenance activities should include periodic mowing (with grass never cut shorter than the design flow depth), weed control, watering during drought conditions, reseeding of bare areas, and clearing of debris and blockages. Cuttings should be removed from the channel and disposed in a local composting facility. Accumulated sediment should also be removed manually to avoid concentrated flows in the swale. The application of fertilizers and pesticides should be minimal.

Another aspect of a good maintenance plan is repairing damaged areas within a channel. For example, if the channel develops ruts or holes, it should be repaired utilizing a suitable soil that is properly tamped and seeded. The grass cover should be thick; if it is not, reseed as necessary. Any standing water removed during the maintenance operation must be disposed to a sanitary sewer at an approved discharge location. Residuals (e.g., silt, grass cuttings) must be disposed in accordance with local or State requirements. Maintenance of grassed swales mostly involves maintenance of the grass or wetland plant cover. Typical maintenance activities are summarized below:

- Inspect swales at least twice annually for erosion, damage to vegetation, and sediment and debris accumulation preferably at the end of the wet season to schedule summer maintenance and before major fall runoff to be sure the swale is ready for winter. However, additional inspection after periods of heavy runoff is desirable. The swale should be checked for debris and litter, and areas of sediment accumulation.

- Grass height and mowing frequency may not have a large impact on pollutant removal. Consequently, mowing may only be necessary once or twice a year for safety or aesthetics or to suppress weeds and woody vegetation.

- Trash tends to accumulate in swale areas, particularly along highways. The need for litter removal is determined through periodic inspection, but litter should always be removed prior to mowing.

- Sediment accumulating near culverts and in channels should be removed when it builds up to 75 mm (3 in.) at any spot, or covers vegetation.

- Regularly inspect swales for pools of standing water. Swales can become a nuisance due to mosquito breeding in standing water if obstructions develop (e.g. debris accumulation, invasive vegetation) and/or if proper drainage slopes are not implemented and maintained.

Cost

Construction Cost

Little data is available to estimate the difference in cost between various swale designs. One study (SWRPC, 1991) estimated the construction cost of grassed channels at approximately \$0.25 per ft^2. This price does not include design costs or contingencies. Brown and Schueler (1997) estimate these costs at approximately 32 percent of construction costs for most stormwater management practices. For swales, however, these costs would probably be significantly higher since the construction costs are so low compared with other practices. A more realistic estimate would be a total cost of approximately \$0.50 per ft^2, which compares favorably with other stormwater management practices.

Table 2 Swale Cost Estimate (SEWRPC, 1991)

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization / Demobilization-Light	Swale	1	$107	$274	$441	$107	$274	$441
Site Preparation								
Clearing[b]	Acre	0.5	$2,200	$3,800	$5,400	$1,100	$1,900	$2,700
Grubbing[c]	Acre	0.25	$3,800	$5,200	$6,600	$950	$1,300	$1,650
General Excavation[d]	Yd^3	372	$2.10	$3.70	$5.30	$781	$1,376	$1,972
Level and Till[e]	Yd^2	1,210	$0.20	$0.35	$0.50	$242	$424	$605
Sites Development								
Salvaged Topsoil Seed, and Mulch[f]	Yd^2	1,210	$0.40	$1.00	$1.60	$484	$1,210	$1,936
Sod[g]	Yd^2	1,210	$1.20	$2.40	$3.60	$1,452	$2,904	$4,356
Subtotal	--	--	--	--	--	$5,116	$9,388	$13,660
Contingencies	Swale	1	25%	25%	25%	$1,279	$2,347	$3,415
Total	--	--	--	--	--	$6,395	$11,735	$17,075

Source: (SEWRPC, 1991)

Note: Mobilization/demobilization refers to the organization and planning involved in establishing a vegetative swale.

[a] Swale has a bottom width of 1.0 foot, a top width of 10 feet with 1:3 side slopes, and a 1,000-foot length.

[b] Area cleared = (top width + 10 feet) x swale length.

[c] Area grubbed = (top width x swale length).

[d] Volume excavated = (0.67 x top width x swale depth) x swale length (parabolic cross-section).

[e] Area tilled = (top width + $\frac{8(\text{swale depth}^2)}{3(\text{top width})}$) x swale length (parabolic cross-section).

[f] Area seeded = area cleared x 0.5.

[g] Area sodded = area cleared x 0.5.

Table 3 Estimated Maintenance Costs (SEWRPC. 1991)

Component	Unit Cost	Swale Size (Depth and Top Width)		Comment
		1.5 Foot Depth, One-Foot Bottom Width, 10-Foot Top Width	3-Foot Depth, 3-Foot Bottom Width, 21-Foot Top Width	
Lawn Mowing	\$0.85 / 1,000 ft²/ mowing	\$0.14 / linear foot	\$0.21 / linear foot	Lawn maintenance area=(top width + 10 feet) x length. Mow eight times per year
General Lawn Care	\$9.00 / 1,000 ft²/ year	\$0.18 / linear foot	\$0.28 / linear foot	Lawn maintenance area = (top width + 10 feet) x length
Swale Debris and Litter Removal	\$0.10 / linear foot / year	\$0.10 / linear foot	\$0.10 / linear foot	–
Grass Reseeding with Mulch and Fertilizer	\$0.30 / yd²	\$0.01 / linear foot	\$0.01 / linear foot	Area revegetated equals 1% of lawn maintenance area per year
Program Administration and Swale Inspection	\$0.15 / linear foot / year, plus \$25 / inspection	\$0.15 / linear foot	\$0.15 / linear foot	Inspect four times per year
Total	--	**\$0.58 / linear foot**	**\$ 0.75 / linear foot**	—

Maintenance Cost

Caltrans (2002) estimated the expected annual maintenance cost for a swale with a tributary area of approximately 2 ha at approximately $2,700. Since almost all maintenance consists of mowing, the cost is fundamentally a function of the mowing frequency. Unit costs developed by SEWRPC are shown in Table 3. In many cases vegetated channels would be used to convey runoff and would require periodic mowing as well, so there may be little additional cost for the water quality component. Since essentially all the activities are related to vegetation management, no special training is required for maintenance personnel.

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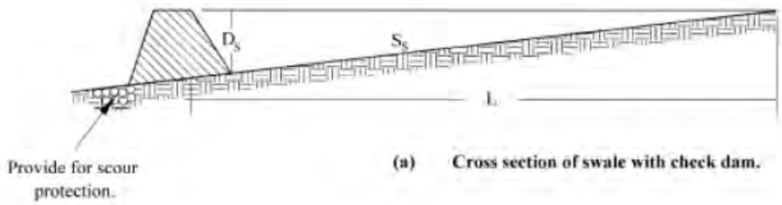
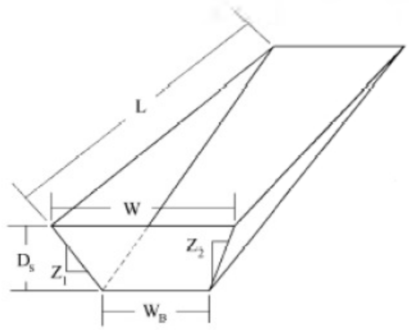


(a) Cross section of swale with check dam.



(b) Dimensional view of swale impoundment area.

Notation:
L = Length of swale impoundment area per check dam (ft)
D_S = Depth of check dam (ft)
S_S = Bottom slpe of swale (ft/ft)
W = Top width of check dam (ft)
W_B = Bottom width of check dam (ft)
$Z_{1\&2}$ = Ratio of horizontal to vertical change in swale side slope (ft/ft)

Design Considerations

- Tributary Area
- Area Required
- Hydraulic Head

Description

Dry extended detention ponds (a.k.a. dry ponds, extended detention basins, detention ponds, extended detention ponds) are basins whose outlets have been designed to detain the stormwater runoff from a water quality design storm for some minimum time (e.g., 48 hours) to allow particles and associated pollutants to settle. Unlike wet ponds, these facilities do not have a large permanent pool. They can also be used to provide flood control by including additional flood detention storage.

California Experience

Caltrans constructed and monitored 5 extended detention basins in southern California with design drain times of 72 hours. Four of the basins were earthen, less costly and had substantially better load reduction because of infiltration that occurred, than the concrete basin. The Caltrans study reaffirmed the flexibility and performance of this conventional technology. The small headloss and few siting constraints suggest that these devices are one of the most applicable technologies for stormwater treatment.

Advantages

- Due to the simplicity of design, extended detention basins are relatively easy and inexpensive to construct and operate.
- Extended detention basins can provide substantial capture of sediment and the toxics fraction associated with particulates.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency

Targeted Constituents

☑	Sediment	▲
☑	Nutrients	●
☑	Trash	■
☑	Metals	▲
☑	Bacteria	▲
☑	Oil and Grease	▲
☑	Organics	▲

Legend *(Removal Effectiveness)*

● Low ■ High

▲ Medium

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relationships resulting from the increase of impervious cover in a watershed.

Limitations

- Limitation of the diameter of the orifice may not allow use of extended detention in watersheds of less than 5 acres (would require an orifice with a diameter of less than 0.5 inches that would be prone to clogging).
- Dry extended detention ponds have only moderate pollutant removal when compared to some other structural stormwater practices, and they are relatively ineffective at removing soluble pollutants.
- Although wet ponds can increase property values, dry ponds can actually detract from the value of a home due to the adverse aesthetics of dry, bare areas and inlet and outlet structures.

Design and Sizing Guidelines

- Capture volume determined by local requirements or sized to treat 85% of the annual runoff volume.
- Outlet designed to discharge the capture volume over a period of hours.
- Length to width ratio of at least 1.5:1 where feasible.
- Basin depths optimally range from 2 to 5 feet.
- Include energy dissipation in the inlet design to reduce resuspension of accumulated sediment.
- A maintenance ramp and perimeter access should be included in the design to facilitate access to the basin for maintenance activities and for vector surveillance and control.
- Use a draw down time of 48 hours in most areas of California. Draw down times in excess of 48 hours may result in vector breeding, and should be used only after coordination with local vector control authorities. Draw down times of less than 48 hours should be limited to BMP drainage areas with coarse soils that readily settle and to watersheds where warming may be determined to downstream fisheries.

Construction/Inspection Considerations

- Inspect facility after first large to storm to determine whether the desired residence time has been achieved.
- When constructed with small tributary area, orifice sizing is critical and inspection should verify that flow through additional openings such as bolt holes does not occur.

Performance

One objective of stormwater management practices can be to reduce the flood hazard associated with large storm events by reducing the peak flow associated with these storms. Dry extended detention basins can easily be designed for flood control, and this is actually the primary purpose of most detention ponds.

Dry extended detention basins provide moderate pollutant removal, provided that the recommended design features are incorporated. Although they can be effective at removing some pollutants through settling, they are less effective at removing soluble pollutants because of the absence of a permanent pool. Several studies are available on the effectiveness of dry extended detention ponds including one recently concluded by Caltrans (2002).

The load reduction is greater than the concentration reduction because of the substantial infiltration that occurs. Although the infiltration of stormwater is clearly beneficial to surface receiving waters, there is the potential for groundwater contamination. Previous research on the effects of incidental infiltration on groundwater quality indicated that the risk of contamination is minimal.

There were substantial differences in the amount of infiltration that were observed in the earthen basins during the Caltrans study. On average, approximately 40 percent of the runoff entering the unlined basins infiltrated and was not discharged. The percentage ranged from a high of about 60 percent to a low of only about 8 percent for the different facilities. Climatic conditions and local water table elevation are likely the principal causes of this difference. The least infiltration occurred at a site located on the coast where humidity is higher and the basin invert is within a few meters of sea level. Conversely, the most infiltration occurred at a facility located well inland in Los Angeles County where the climate is much warmer and the humidity is less, resulting in lower soil moisture content in the basin floor at the beginning of storms.

Vegetated detention basins appear to have greater pollutant removal than concrete basins. In the Caltrans study, the concrete basin exported sediment and associated pollutants during a number of storms. Export was not as common in the earthen basins, where the vegetation appeared to help stabilize the retained sediment.

Siting Criteria

Dry extended detention ponds are among the most widely applicable stormwater management practices and are especially useful in retrofit situations where their low hydraulic head requirements allow them to be sited within the constraints of the existing storm drain system. In addition, many communities have detention basins designed for flood control. It is possible to modify these facilities to incorporate features that provide water quality treatment and/or channel protection. Although dry extended detention ponds can be applied rather broadly, designers need to ensure that they are feasible at the site in question. This section provides basic guidelines for siting dry extended detention ponds.

In general, dry extended detention ponds should be used on sites with a minimum area of 5 acres. With this size catchment area, the orifice size can be on the order of 0.5 inches. On smaller sites, it can be challenging to provide channel or water quality control because the orifice diameter at the outlet needed to control relatively small storms becomes very small and thus prone to clogging. In addition, it is generally more cost-effective to control larger drainage areas due to the economies of scale.

Extended detention basins can be used with almost all soils and geology, with minor design adjustments for regions of rapidly percolating soils such as sand. In these areas, extended detention ponds may need an impermeable liner to prevent ground water contamination.

The base of the extended detention facility should not intersect the water table. A permanently wet bottom may become a mosquito breeding ground. Research in Southwest Florida (Santana et al., 1994) demonstrated that intermittently flooded systems, such as dry extended detention ponds, produce more mosquitoes than other pond systems, particularly when the facilities remained wet for more than 3 days following heavy rainfall.

A study in Prince George's County, Maryland, found that stormwater management practices can increase stream temperatures (Galli, 1990). Overall, dry extended detention ponds increased temperature by about 5°F. In cold water streams, dry ponds should be designed to detain stormwater for a relatively short time (i.e., 24 hours) to minimize the amount of warming that occurs in the basin.

Additional Design Guidelines

In order to enhance the effectiveness of extended detention basins, the dimensions of the basin must be sized appropriately. Merely providing the required storage volume will not ensure maximum constituent removal. By effectively configuring the basin, the designer will create a long flow path, promote the establishment of low velocities, and avoid having stagnant areas of the basin. To promote settling and to attain an appealing environment, the design of the basin should consider the length to width ratio, cross-sectional areas, basin slopes and pond configuration, and aesthetics (Young et al., 1996).

Energy dissipation structures should be included for the basin inlet to prevent resuspension of accumulated sediment. The use of stilling basins for this purpose should be avoided because the standing water provides a breeding area for mosquitoes.

Extended detention facilities should be sized to completely capture the water quality volume. A micropool is often recommended for inclusion in the design and one is shown in the schematic diagram. These small permanent pools greatly increase the potential for mosquito breeding and complicate maintenance activities; consequently, they are not recommended for use in California.

A large aspect ratio may improve the performance of detention basins; consequently, the outlets should be placed to maximize the flowpath through the facility. The ratio of flowpath length to width from the inlet to the outlet should be at least 1.5:1 (L:W) where feasible. Basin depths optimally range from 2 to 5 feet.

The facility's drawdown time should be regulated by an orifice or weir. In general, the outflow structure should have a trash rack or other acceptable means of preventing clogging at the entrance to the outflow pipes. The outlet design implemented by Caltrans in the facilities constructed in San Diego County used an outlet riser with orifices

Figure 1
Example of Extended Detention Outlet Structure

sized to discharge the water quality volume, and the riser overflow height was set to the design storm elevation. A stainless steel screen was placed around the outlet riser to ensure that the orifices would not become clogged with debris. Sites either used a separate riser or broad crested weir for overflow of runoff for the 25 and greater year storms. A picture of a typical outlet is presented in Figure 1.

The outflow structure should be sized to allow for complete drawdown of the water quality volume in 72 hours. No more than 50% of the water quality volume should drain from the facility within the first 24 hours. The outflow structure can be fitted with a valve so that discharge from the basin can be halted in case of an accidental spill in the watershed.

Summary of Design Recommendations

(1) Facility Sizing - The required water quality volume is determined by local regulations or the basin should be sized to capture and treat 85% of the annual runoff volume. See Section 5.5.1 of the handbook for a discussion of volume-based design.

Basin Configuration – A high aspect ratio may improve the performance of detention basins; consequently, the outlets should be placed to maximize the flowpath through the facility. The ratio of flowpath length to width from the inlet to the outlet should be at least 1.5:1 (L:W). The flowpath length is defined as the distance from the inlet to the outlet as measured at the surface. The width is defined as the mean width of the basin. Basin depths optimally range from 2 to 5 feet. The basin may include a sediment forebay to provide the opportunity for larger particles to settle out.

A micropool should not be incorporated in the design because of vector concerns. For online facilities, the principal and emergency spillways must be sized to provide 1.0 foot of freeboard during the 25-year event and to safely pass the flow from 100-year storm.

(2) Pond Side Slopes - Side slopes of the pond should be 3:1 (H:V) or flatter for grass stabilized slopes. Slopes steeper than 3:1 (H:V) must be stabilized with an appropriate slope stabilization practice.

(3) Basin Lining – Basins must be constructed to prevent possible contamination of groundwater below the facility.

(4) Basin Inlet – Energy dissipation is required at the basin inlet to reduce resuspension of accumulated sediment and to reduce the tendency for short-circuiting.

(5) Outflow Structure - The facility's drawdown time should be regulated by a gate valve or orifice plate. In general, the outflow structure should have a trash rack or other acceptable means of preventing clogging at the entrance to the outflow pipes.

The outflow structure should be sized to allow for complete drawdown of the water quality volume in 72 hours. No more than 50% of the water quality volume should drain from the facility within the first 24 hours. The outflow structure should be fitted with a valve so that discharge from the basin can be halted in case of an accidental spill in the watershed. This same valve also can be used to regulate the rate of discharge from the basin.

The discharge through a control orifice is calculated from:

$$Q = CA(2g(H-H_o))^{0.5}$$

where:
- Q = discharge (ft^3/s)
- C = orifice coefficient
- A = area of the orifice (ft^2)
- g = gravitational constant (32.2)
- H = water surface elevation (ft)
- H_o= orifice elevation (ft)

Recommended values for C are 0.66 for thin materials and 0.80 when the material is thicker than the orifice diameter. This equation can be implemented in spreadsheet form with the pond stage/volume relationship to calculate drain time. To do this, use the initial height of the water above the orifice for the water quality volume. Calculate the discharge and assume that it remains constant for approximately 10 minutes. Based on that discharge, estimate the total discharge during that interval and the new elevation based on the stage volume relationship. Continue to iterate until H is approximately equal to H_o. When using multiple orifices the discharge from each is summed.

(6) Splitter Box - When the pond is designed as an offline facility, a splitter structure is used to isolate the water quality volume. The splitter box, or other flow diverting approach, should be designed to convey the 25-year storm event while providing at least 1.0 foot of freeboard along pond side slopes.

(7) Erosion Protection at the Outfall - For online facilities, special consideration should be given to the facility's outfall location. Flared pipe end sections that discharge at or near the stream invert are preferred. The channel immediately below the pond outfall should be modified to conform to natural dimensions, and lined with large stone riprap placed over filter cloth. Energy dissipation may be required to reduce flow velocities from the primary spillway to non-erosive velocities.

(8) Safety Considerations - Safety is provided either by fencing of the facility or by managing the contours of the pond to eliminate dropoffs and other hazards. Earthen side slopes should not exceed 3:1 (H:V) and should terminate on a flat safety bench area. Landscaping can be used to impede access to the facility. The primary spillway opening must not permit access by small children. Outfall pipes above 48 inches in diameter should be fenced.

Maintenance

Routine maintenance activity is often thought to consist mostly of sediment and trash and debris removal; however, these activities often constitute only a small fraction of the maintenance hours. During a recent study by Caltrans, 72 hours of maintenance was performed annually, but only a little over 7 hours was spent on sediment and trash removal. The largest recurring activity was vegetation management, routine mowing. The largest absolute number of hours was associated with vector control because of mosquito breeding that occurred in the stilling basins (example of standing water to be avoided) installed as energy dissipaters. In most cases, basic housekeeping practices such as removal of debris accumulations and vegetation management to ensure that the basin dewaters completely in 48-72 hours is sufficient to prevent creating mosquito and other vector habitats.

Consequently, maintenance costs should be estimated based primarily on the mowing frequency and the time required. Mowing should be done at least annually to avoid establishment of woody vegetation, but may need to be performed much more frequently if aesthetics are an important consideration.

Typical activities and frequencies include:

- Schedule semiannual inspection for the beginning and end of the wet season for standing water, slope stability, sediment accumulation, trash and debris, and presence of burrows.
- Remove accumulated trash and debris in the basin and around the riser pipe during the semiannual inspections. The frequency of this activity may be altered to meet specific site conditions.
- Trim vegetation at the beginning and end of the wet season and inspect monthly to prevent establishment of woody vegetation and for aesthetic and vector reasons.
- Remove accumulated sediment and re-grade about every 10 years or when the accumulated sediment volume exceeds 10 percent of the basin volume. Inspect the basin each year for accumulated sediment volume.

Cost

Construction Cost

The construction costs associated with extended detention basins vary considerably. One recent study evaluated the cost of all pond systems (Brown and Schueler, 1997). Adjusting for inflation, the cost of dry extended detention ponds can be estimated with the equation:

$$C = 12.4V^{0.760}$$

where: C = Construction, design, and permitting cost, and
V = Volume (ft^3).

Using this equation, typical construction costs are:

$ 41,600 for a 1 acre-foot pond

$ 239,000 for a 10 acre-foot pond

$ 1,380,000 for a 100 acre-foot pond

Interestingly, these costs are generally slightly higher than the predicted cost of wet ponds (according to Brown and Schueler, 1997) on a cost per total volume basis, which highlights the difficulty of developing reasonably accurate construction estimates. In addition, a typical facility constructed by Caltrans cost about $160,000 with a capture volume of only 0.3 ac-ft.

An economic concern associated with dry ponds is that they might detract slightly from the value of adjacent properties. One study found that dry ponds can actually detract from the perceived value of homes adjacent to a dry pond by between 3 and 10 percent (Emmerling-Dinovo, 1995).

Maintenance Cost

For ponds, the annual cost of routine maintenance is typically estimated at about 3 to 5 percent of the construction cost (EPA website). Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Table 1 presents the maintenance costs estimated by Caltrans based on their experience with five basins located in southern California. Again, it should be emphasized that the vast majority of hours are related to vegetation management (mowing).

Table 1 Estimated Average Annual Maintenance Effort

Activity	Labor Hours	Equipment & Material ($)	Cost
Inspections	4	7	183
Maintenance	49	126	2282
Vector Control	0	0	0
Administration	3	0	132
Materials	-	535	535
Total	**56**	**$668**	**$3,132**

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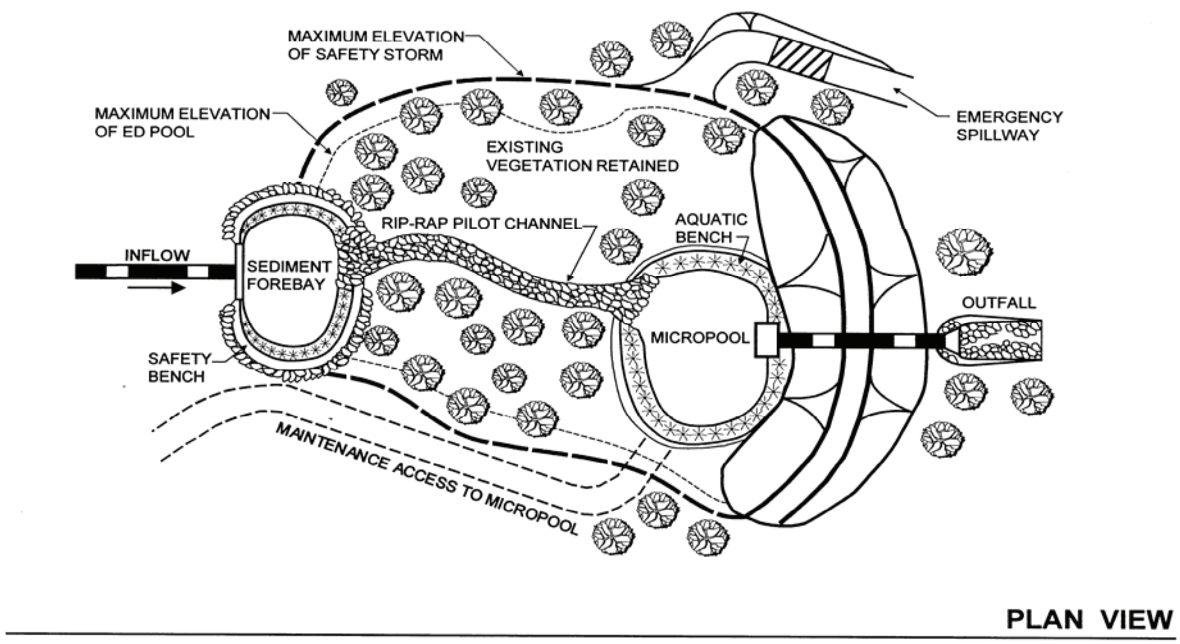

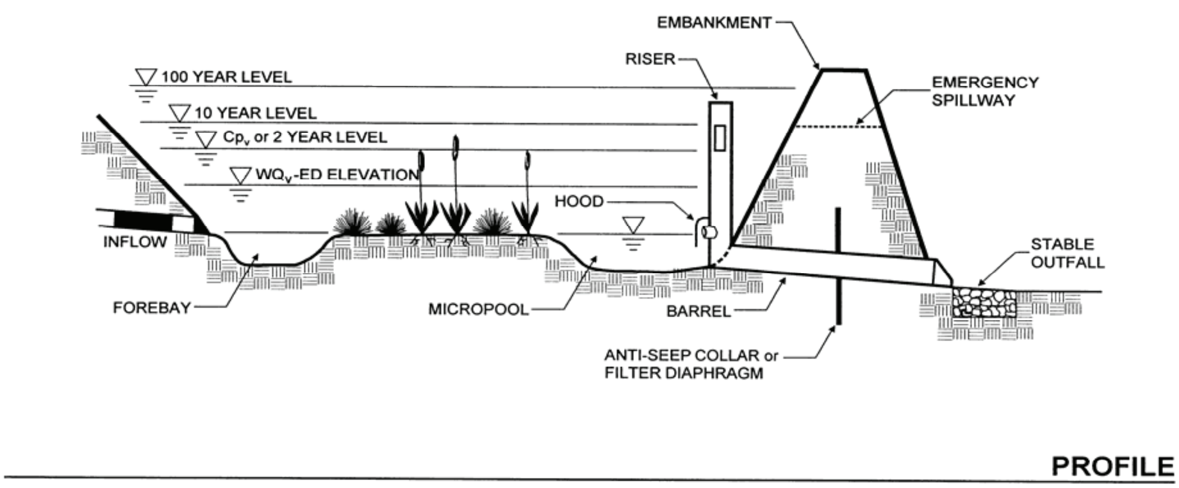

Schematic of an Extended Detention Basin (MDE, 2000)