KNIGHTSEN
WATER QUALITY WETLAND
FEASIBILITY ASSESSMENT

Philip Williams & Associates, Ltd.
Consultants in Hydrology

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Prepared for
Contra Costa County – Public Works Department

Prepared by
Philip Williams & Associates, Ltd.

Sponsored by
Knightsen – Town Advisory Council
US Environmental Protection Agency
Calfed Bay - Delta Program
Contra Costa County Public Works Department

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PWA REF. # 1565

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Bob Pastor, Knightsen Fire Department
Kevin Emigh and Rachael Canapa, Contra Costa County Public Works Department
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1. INTRODUCTION

The CALFED Veale/Byron Tract Work Group has worked with the community of Knightsen to develop a plan to improve stormwater quality and reduce flood hazards in the Knightsen area. The plan, which is being administered by the Contra Costa County Flood Control and Water Conservation District (District), includes developing a Community Services District, establishing assessments for drainage infrastructure maintenance, and assessing the feasibility of building water quality facilities such as wetland biofilters to treat runoff from the Knightsen area. This study addresses the third element of the plan.

The District contracted with Philip Williams & Associates, Ltd. (PWA) to assess the feasibility of constructing facilities to help improve the water quality of stormwater and agricultural tailwaters from the Knightsen area before they enter the Delta. The primary goal of this study is to determine the feasibility of developing one or more wetland biofilters or other treatment best management practices ("BMPs") to improve water quality of runoff discharging to the Delta. A secondary goal is to improve drainage in the Knightsen area in conjunction with development of a water quality facility or facilities. The current study constitutes Phase I of a two-phase project. In Phase II, PWA will build on this study to refine the wetland concept and provide additional analyses necessary to implement the project. The District is working to secure funding for Phase II.

To assess the feasibility of water quality BMPs for the Knightsen area, PWA first reviewed local conditions and developed estimates of runoff volumes and peak flows from the Knightsen watershed (Chapter 2). This information was then used to evaluate various BMP options and develop a conceptual implementation plan (Chapter 3). Finally, PWA assessed the capacity of the existing drainage network with respect to its ability to convey runoff from the Knightsen area to potential water quality facilities (Chapter 4), and made recommendations for drainage system improvements.

1.1 PROJECT AREA

Knightsen is an unincorporated community in eastern Contra Costa County, east of Marsh Creek and west of Veale Tract (Figure 1). It is located on the San Joaquin Delta, resulting in topography that is generally flat with a very gentle overall slope of approximately 0.3% toward the northeast. Ground elevations range from somewhat below sea level (-5 feet NGVD) at Veale Tract to approximately 25 feet National Geodetic Vertical Datum (NGVD) in the town center and 65 feet NGVD in the southwest limits of the contributing watershed. Natural surface drainage is generally toward the northeast and into the Delta, but pumping into drainage and agricultural ditches drains much of the area. Historically, the area probably drained as sheet flow and in shallow channels to wetlands that lined the fringe of the Delta. The flat topography, combined with a variety of constructed features such as railroad tracks, roads, and levees, restricts drainage and results in frequent flooding in some areas of the community.

Rock Slough and the Contra Costa Canal, located immediately east/northeast of Knightsen, are sources of agricultural, industrial and municipal water for the region. Therefore, there is increasing interest in maintaining and improving the water quality of runoff entering the Delta in the Knightsen area. Rock Slough is contained by levees, and the mean water level in Rock Slough is as much as 4 feet higher than the surrounding ground surface (1.4 feet NGVD vs. –5.0 feet NGVD).

Agricultural discharge and stormwater runoff have been identified as a source of pollutants in Rock Slough and the Contra Costa Canal (Contra Costa Water District, 2001; Flett, 1985). Previous studies have identified elevated levels of total dissolved solids, salinity (chlorides, sodium, bromides, etc.), total organic carbon, and potentially elevated levels of nutrients and pathogens including coliform bacteria as water quality constituents of concern for the area (Contra Costa Water District, 2001). Future phases of this study will include additional water quality sampling to identify specific contaminants to be targeted by future facilities.

1.2 EXISTING INFORMATION

As background to preparing this report, PWA reviewed the following studies related to flooding and drainage issues in the Knightsen area.

East Knightsen Drainage Study. D.B. Flett & Associates (April 4, 1985)
This study focused on two areas: the portion of the watershed that lies east of the Atchison Topeka and Santa Fe railroad tracks (1100 acres), and a larger area from Marsh Creek to Rock and No Name Sloughs and from Delta Road to Sunset Road (3800 acres). Peak flow (Q100) and runoff volume (V100) for the 100-year storm were estimated for each of the two areas (Q100 = 215 cubic feet per second (cfs), V100 = 52.57 acre-feet for the 1100-acre watershed and Q100 = 395 cfs, V100 = 113.81 acre-feet for the 3800 acre watershed). The report also described two detention basin alternatives designed to discharge via pumping. The study noted that the northeastern portion of Veale Tract is below sea level and is useable only through consistent pumping.

Engineer's Report for a Flood Improvement Project in the East Knightsen Area of Contra Costa County. Contra Costa County Flood Control and Water Conservation District (August 1985)
This report followed up on consideration of the 1100 acre watershed described in the East Knightsen Drainage Study, and provides recommendations regarding alternatives presented there. These recommendations include developing the "Eden Plains Earth Channel" between the railroad culvert and No Name Slough, and the "Line A Earth Channel" from Byron Hwy to No Name Slough. The report also includes discussion of three detention basin alternatives, the Recommended Alternative (26-acre basin at Rock Slough, discharge pumped to Line A channel), Alternative A (33-acre basin at Rock Slough takes all flows, discharge pumped to Eden Plains Channel), and Alternative B (17-acre basin at Rock Slough takes flows from Tule Lane and Knightsen Triangle areas, discharge pumped to Eden Plains Channel).

Knightsen – Drainage Improvement Assessment. Mattern and Associates (April 7, 1998)
This report includes a preliminary feasibility evaluation of various proposed solutions to flooding problems, and describes major culverts in the existing drainage network. The report did not include sizing or cost estimates for the recommended improvements, and the plan was never implemented.

Finally, PWA interviewed local Knightsen residents knowledgeable about historical flooding and drainage issues, including Seth Cockrell of the Knightsen Town Advisory Council and Bob Pastor of the Knightsen Fire Department.

2. HYDROLOGY

Knowledge of local hydrology is key in evaluating the feasibility of routing stormwater runoff to and through potential water quality facilities before discharging to the local slough system. Estimates of peak discharge and runoff volume are also needed to develop preliminary facility design concepts and sizing estimates. Therefore, in addition to reviewing existing hydrology information provided by the reports described in Section 2.3, PWA estimated peak discharge and runoff volumes for various locations in the Knightsen drainage area. We also reviewed groundwater depth and elevation data collected by Contra Costa County Irrigation District to estimate excavation limits for drainage and water quality facilities. Tidal elevation data for No Name Slough and Rock Slough were examined to determine potential tail water effects on discharge from drainage features and water quality facilities. These assessments are described in the following sections.

2.1 RUNOFF ESTIMATES

As described below, PWA estimated peak discharge and runoff volume at various locations in the Knightsen drainage area for multiple storm events to help characterize the hydrology of the system. Peak discharge rate estimates were used to evaluate sizing of existing and proposed drainage features. Runoff volumes for small, frequent storms and larger, extreme events were estimated in order to evaluate water quality facility sizing options.

2.1.1 Subwatershed Delineation

The Knightsen drainage area includes approximately 10.6 square miles bounded by Cypress Road to the north, Marsh Creek and Highway 4 to the west, the PG&E easement and the Contra Costa Canal to the east, and extends south past the Mokelumne Aqueduct to Orwood Road. The land is relatively flat with slopes of 0.2 to 0.3% towards the northeast. Soils in the area are generally poorly drained clays and silty clays. The land use is generally agricultural and pastureland with a small area of development within central Knightsen (Flett, 1985).

To determine peak discharge and runoff volume at different locations within the watershed, PWA divided the Knightsen drainage area into 10 sub-watersheds (WS) (Figure 1) described below:

- WS#1: Northwest Knightsen – 396 acres in the northwest corner of Knightsen, south of Cypress Road, east of Marsh Creek, and west of Sellers Avenue. WS#1 drains to the north into a ditch at a siphon in the Contra Costa Canal.

- WS#2: Northeast Knightsen – 950 acres in the northeast corner of Knightsen, south of Cypress Road, east of Sellers Avenue, west of the Contra Costa Canal, and north of Tule Lane. WS#2 drains to the north into a ditch at a siphon in the Contra Costa Canal.

- WS#3: Central Knightsen – 321 acres including the town of Knightsen, southwest of the Sante Fe railroad tracks, east of Marsh Creek, and north of Delta Road. WS#3 drains to the southeast and crosses Delta Road in a 24-inch diameter culvert at the intersection of the Sante Fe railroad tracks.

- WS#4: Tule Lane – 684 acres south of Tule Lane and Rock Slough, east of Knightsen Avenue and the Sante Fe railroad tracks, north of Delta Road, and extends east past the PG&E lines. WS#4 drains to the east to Rock Slough and experiences frequent flooding along small levees and farm roads.

- WS#5: Southwest Knightsen – 1537 acres in southwest Knightsen south of Delta Road, east of Marsh Creek and Highway 4, and west of Eden Plains Road. WS#5 drains to the northeast and crosses Eden Plains Road in an 18-inch diameter corrugated metal culvert just south of the Sante Fe railroad tracks.

- WS#6: South Knightsen – 1146 acres in south-central Knightsen south and west of the Sante Fe railroad tracks and east of WS#5. WS#6 drains to the northeast and crosses the Sante Fe railroad tracks in a 2.5-foot wide x 3-foot tall box culvert. A pair of 24-inch diameter corrugated metal culverts are located higher above the ground and would require exceptionally high water to provide additional discharge.

- WS#7: Delta Road – 189 acres in the northwestern portion of the triangle formed by Byron Hwy, Delta Rd, and the railroad tracks. WS#7 drains to the northeast in a drainage ditch on the south side of the Delta Road and crosses Byron Highway in a 24-inch diameter corrugated metal culvert at the intersection of Delta Road.

- WS#8: Byron Highway – 235 acres in the southeastern portion of the triangle formed by Byron Hwy, Delta Rd, and the railroad tracks. WS#8 drains to the northeast in a drainage ditch on the west side of Byron Highway and crosses Byron Highway in a 24-inch diameter corrugated metal culvert at the intersection of Delta Road.

- WS#9: Veale Tract – 473 acres of the Veale Tract in east-central Knightsen east of Byron Highway between Delta Road and Sunset Road. WS#9 drains to the northeast in a drainage ditch on the south side of the Delta Road, a drainage ditch east of the PG&E easement and into No Name Slough through a culvert with a flap gate to prevent water from the Delta from entering the drainage ditch.

- WS#10: Southeast Knightsen – 875 acres in southeast Knightsen near Bixler between Sunset Road and Orwood Road. WS#10 drains to the northwest into No Name Slough.

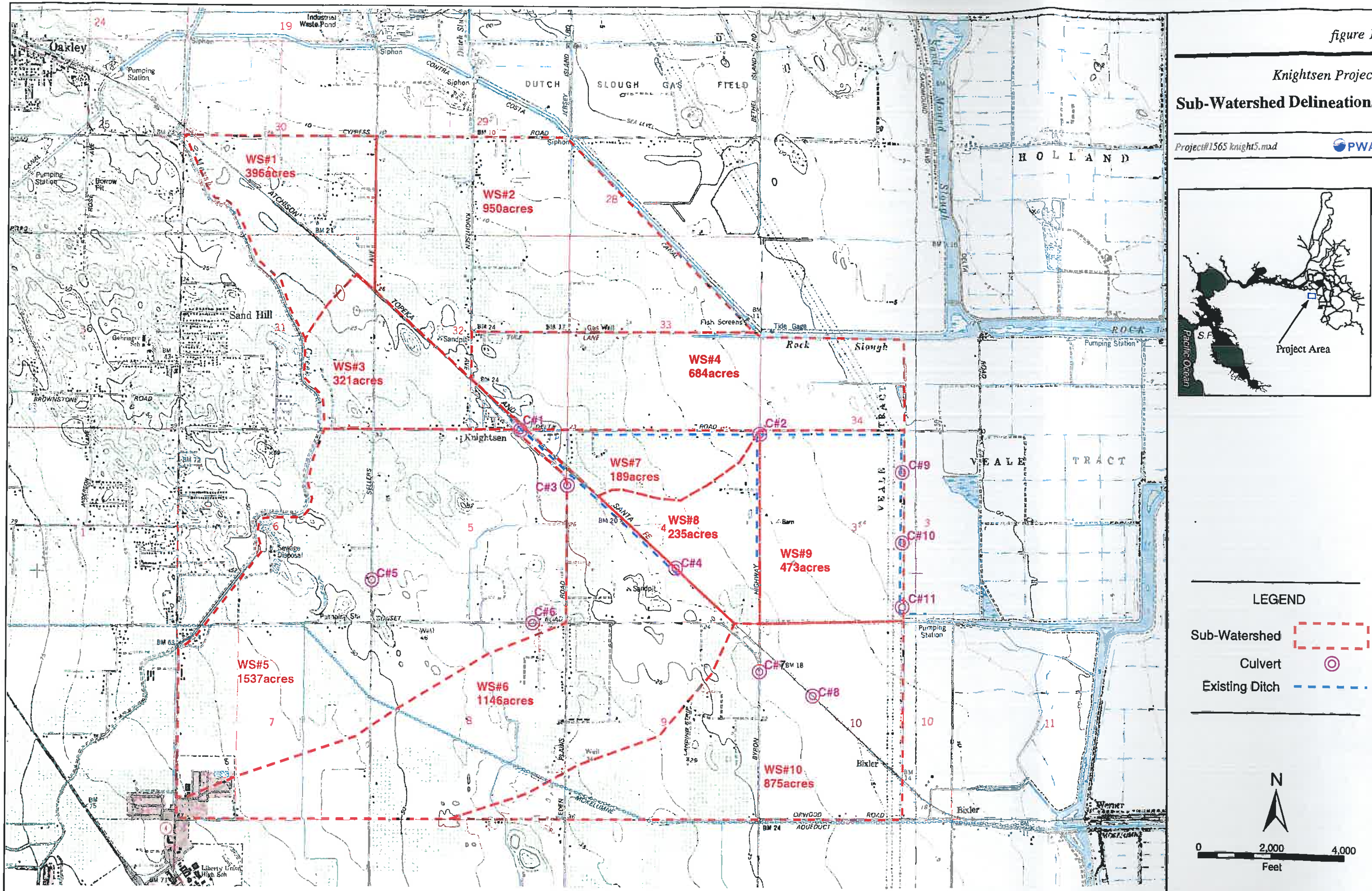


figure 1

Knightsen Project

Sub-Watershed Delineations

There is an irrigation canal that begins further south near Main Canal and ends within Southeast Knightsen (WS#5). Although there is evidence that water may pond within this canal during high run-off generating events (Mattern & Associates, 1998), the effect of this ponding on peak discharge calculations was not considered in this analysis.

Overall, WS#3, WS#5, and WS#6 (Central, Southeast, and South Knightsen) combine and cross under the Santa Fe railroad tracks in the box culvert. The discharge from WS#3, WS#5, WS#6, and WS#8 (Central, Southeast, and South Knightsen, and Byron Highway) drain into the drainage ditch on the west side of Byron Highway. WS#7 (Delta Road) drains into the drainage ditch on the south side of Delta Road. The discharge from WS#3, WS#5, WS#6, WS#7 and WS#8 (Central, Southeast, and South Knightsen, Delta Road, and Byron Highway) combine in a 24-inch diameter corrugated metal culvert at the intersection of Delta Road and Byron Highway and continues to flow east along Delta Road. The discharge from WS#9 (Veale Tract) flows towards Delta Road and combines with the discharge from the upstream sub-watersheds in the region where Delta Road and the PG&E easement intersect.

2.1.2 Peak Discharge

PWA used the Rational Method to estimate peak discharge at a variety of locations within the larger Knightsen watershed. Details of this method are presented in Appendix A. The peak discharge for each sub-watershed is presented in Table 1. Table 1 also presents the estimated cumulative peak discharge at key points within the drainage network, representing the effects of flow routing.

Table 1. Estimated Peak Discharge Summary

Watershed	Area (acres)	100-year Q (cfs)	50-year Q (cfs)	25-year Q (cfs)	10-year Q (cfs)
WS#1: Northwest Knightsen	396	98	80	69	53
WS#2: Northeast Knightsen	950	195	171	142	111
WS#3: Central Knightsen	321	59	51	42	33
WS#4: Tule Lane	684	96	83	65	51
WS#5: Southwest Knightsen	1537	207	175	147	111
WS#6: South Knightsen	1146	151	129	106	81
WS#7: Delta Road	189	40	34	29	22
WS#8: Byron Highway	235	56	46	39	31
WS#9: Veale Tract	473	98	84	72	55
WS#10: Southeast Knightsen	875	132	118	98	73

Watershed	Area (acres)	100-year Q (cfs)	50-year Q (cfs)	25-year Q (cfs)	10-year Q (cfs)
Cumulative Watersheds					
WS#1 & WS#2	1346	201	180	149	114
WS#3, WS#5, & WS#6	3004	340	293	239	181
WS#3, #5, #6, & #8	3239	318	277	220	169
WS#3, #5, #6, #7, & #8	3428	336	294	233	179
WS#3, #5, #6, #7, #8 & #9	3901	341	299	236	179

PWA did not consider the size of existing culverts in estimating peak flows for this feasibility study. The estimates presented in Table 1 therefore represent the maximum peak discharge rates, and actual peak discharge for combined sub-watersheds may be limited by the conveyance capacity of existing culverts (see Section 4.2.4).

For 10-year return period events:

- WS#3, WS#5, and WS#6 (Central, Southeast and South Knightsen) combine to produce an estimated peak discharge of 181 cfs at the box culvert at the Sante Fe railroad tracks (C#4 on Figure 1).

- Due to routing effects, when WS#7 and WS#8 (Delta Road and Byron Highway) combine with discharge from WS#3, WS#5, and WS#6, the estimated peak discharge is 179 cfs at the intersection of Delta Road and Byron Highway (C#2 on Figure 1).

- Due to routing effects, combining WS#9 (Veale Tract) with discharge from WS#3, WS#5, WS#6, WS#7, and WS#8 does not produce an increase in the estimated peak discharge. The total peak discharge estimated in the drainage ditch at the PG&E easement on the Veale Tract was 179 cfs (C#9, C#10, and C#11 on Figure 1).

2.1.3 Runoff Volume

PWA estimated runoff volumes for 10-year and 100-year storm events with 12-hour and 24-hour durations for the Knightsen drainage area on a sub-watershed scale. These estimates represent runoff from 24-hour storms with a 10-year (10% probability of occurrence in any given year), and 100-year (1% probability of occurrence in any given year) recurrence interval, respectively. Surface runoff volumes were estimated for each sub-watershed and cumulatively at key points using the SCS curve number equation developed by the Natural Resource Conservation Service (Haan et al, 1994). Details of this calculation are presented in Appendix B. The runoff volume estimates for the ten sub-watersheds within the Knightsen drainage area are presented in Table 2.

Table 2. Runoff Volume Estimate Summary

Watershed	Area (acres)	100-year 12-hour V (acre-feet)	100-year 24-hour V (acre-feet)	10-year 12-hour V (acre-feet)	10-year 24-hour V (acre-feet)
WS#1: Northwest Knightsen	396	22	39	7.9	16.5
WS#2: Northeast Knightsen	950	53	93	19.0	39.5
WS#3: Central Knightsen	321	18	31	6.4	13.3
WS#4: Tule Lane	684	38	67	13.7	28.5
WS#5: Southwest Knightsen	1537	85	150	30.8	64.0
WS#6: South Knightsen	1146	64	112	23.0	47.7
WS#7: Delta Road	189	10	18	3.8	7.9
WS#8: Byron Highway	235	13	23	4.7	9.8
WS#9: Veale Tract	473	26	46	9.5	19.7
WS#10: Southeast Knightsen	875	49	85	17.5	36.4

On a cumulative basis, runoff volumes were estimated at the following key points in the watershed:

- WS#3, WS#5, and WS#6 (Central, Southeast and South Knightsen) combined to generate 125 acre-feet (10-year, 24-hour event) and 293 acre-feet (100-year 24-hour event) of runoff at the box culvert that crosses the Santa Fe railroad (C#4 on Figure 1);

- Adding WS#7 and WS#8 (Delta Road and Byron Highway) generates 143 acre-feet (10-year, 24-hour event) and 335 acre-feet (100-year, 24-hour event) of runoff at culvert that crosses Byron Highway at the intersection of Delta Road (C#2 on Figure 1);

- Adding WS#9 (Veale Tract) generates 162 acre-feet (10-year, 24-hour event) and 381 acre-feet (100-year, 24-hour event) of runoff in the drainage ditch at the PR&E easement on the Veale Tract (C#9, C#10, and C#11 on Figure 1).

2.2 GROUNDWATER

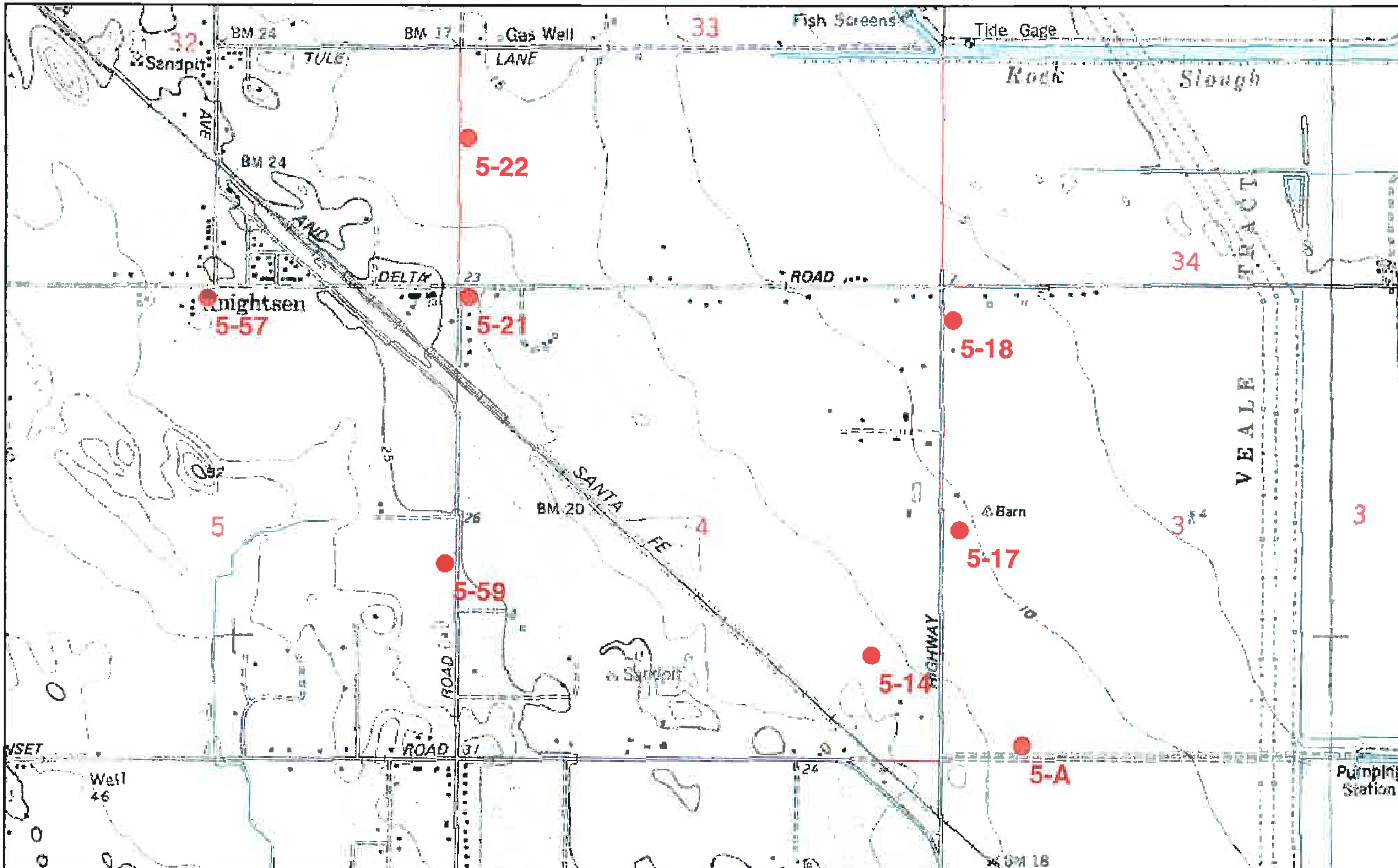
Depth to groundwater can be an important consideration in determining excavation depths for drainage features and wetlands. The East Contra Costa Irrigation District (ECCID) collected depth to groundwater measurements in piezometers throughout the Knightsen drainage area since 1984. PWA collected additional depth to groundwater measurements and surveyed top of casing elevations for piezometers located along Delta Road and Byron Highway in December 2001 and January 2002. Locations of piezometers within the Knightsen drainage area are presented on Figure 2. Table 3 presents a summary of depth to groundwater data collected since 1984. Appendix C contains complete piezometer data.

Table 3. Piezometer Depth to Groundwater Summary Table

Piezometer	**5-A**	**5-14**	**5-17**	**5-18**	**5-21**	**5-22**	**5-57**	**5-59**
WET SEASON AVERAGE DEPTH TO WATER (feet below ground surface)	7.50	2.13	3.86	0.42	7.14	4.21	2.07	5.44
Dry Season Average Depth to Water (feet below ground surface)	7.90	3.90	6.48	3.41	8.57	6.28	3.94	7.82

Piezometers 5-A, 5-14, 5-17, and 5-18 are located along Byron Highway between Eagle Lane and Delta Road as shown on Figure 2. In general, depth to water and groundwater elevation decrease from south to north along Byron Highway.

Measurements collected during the dry season, indicate that: average depth to groundwater decreased from 7.90 feet below ground surface (bgs) (7.03 ft NGVD) in PZ 5-A at Eagle Lane to 3.41 feet bgs (2.28 ft NGVD) in PZ 5-18 at Delta Road. During the wet season, groundwater levels increase as a result of infiltration to the subsurface. Measurements collected during the wet season indicate that: average depth to groundwater decreased from 7.50 feet bgs (7.43 feet NGVD) in PZ 5-A at Eagle Lane to 0.42 feet bgs (5.27 feet NGVD) in PZ 5-18 at Delta Road. During the floods of February 1998, depth to groundwater ranged from 0.42 feet bgs in PZ 5-17 to ground surface and above in PZ 5-14 and PZ 5-18, respectively. Piezometers 5-21, 5-22, 5-57, and 5-59 are located in the vicinity of the town of Knightsen along Eden Plains Road and Delta Road as shown on Figure 2. In general, groundwater elevation decreases from west to east along Delta Road, and when considered with the data collected along Byron Highway, indicates that groundwater flows to the northeast towards the Delta. PZ 5-57 located at Delta Road and Curlew Connex Road, an area that experiences frequent flooding, exhibits relatively low depth to groundwater measurements. Depth to groundwater in PZ 5-57 averaged 3.94 feet bgs during the dry season and 2.07 feet bgs during the wet season, indicating that, within the local depression, groundwater is relatively close to the ground surface. In the other three piezometers, 5-21, 5-22, and 5-59, depth to groundwater averages ranged from 6.28 to 8.57 feet bgs during the dry season and from 4.21 to 7.14 feet bgs during the wet season.



N

0 — 2,000 — 4,000

Feet

Legend:

● Piezometers

figure 2

Knightsen Project

Piezometer Locations

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PWA

2.3 TIDE ELEVATIONS

This report assumes that any water quality BMP facilities proposed for the Knightsen area will ultimately discharge into the local slough system. Since ground elevations in northeast Knightsen are at or below sea level, the water level in the receiving slough is an important consideration in assessing the feasibility of BMP options. PWA therefore assessed water levels in Rock Slough and No Name Slough as part of this study.

Rock Slough is the intake for the Contra Costa Canal which provides drinking water for Contra Costa County. Due to water quality concerns related to Rock Slough and the Contra Costa Canal, this study considered No Name Slough in southeast Knightsen as the preferred discharge location for any future facilities. Although there is not a tide gage on No Name Slough, water surface elevations in Rock Slough are measured at a tide gage near the bend at the Contra Costa Canal. Water surface elevations in No Name Slough and Rock Slough should be similar because both sloughs combine in a common slough channel and flow into the Old River east of Knightsen. To confirm this assumption, PWA surveyed water surface elevations in No Name Sough on January 16, 2002 (2.2 feet NGVD at 9:23 am and 1.4 feet NGVD at 2:37 pm). Water surface elevations measured by the tide gauge in Rock Slough were 1.9 and 1.0 feet NGVD for approximately the same times (California Department of Water Resources, 2002, interpolated). As a result of these observations, this report assumes that water surface elevations measured at Rock Slough approximately represent water surface elevations in No Name Slough.

To illustrate typical tidal elevations during the dry season, water surface elevations measured in Rock Slough during August and September 2001 are presented in Appendix D. The tide signal from August and September 2001, summarized in Table 4, illustrates typical tidal elevations without the effects of a storm surge. The average water surface elevations in Rock Slough during August and September 2001 were 1.38 and 1.39 feet NGVD respectively, and average daily high water levels were 3.13 and 3.01 feet NGVD, respectively.

During the rainy season, tidal elevations in Rock Slough and No Name Slough are potentially influenced by tides, storm surge and runoff in the Delta. To illustrate this effect, tidal statistics computed for February and March 1998, a period of heavy rainfall, are also presented in Table 4. The effects of storm surge and runoff in the Delta resulted in an increase of 2.43 feet NGVD in the average water surface elevation for February 1998 as compared to August 2001. Complete water level data for this period are presented in Appendix D.

Table 4. Rock Slough Tidal Statistics

	February 1998 (feet NGVD)	March 1998 (feet NGVD)	August 2001 (feet NGVD)	September 2001 (feet NGVD)
Maximum Water Surface	6.77	4.70	3.51	3.59
Mean Daily High Water, (MHW)	5.27	3.99	3.13	3.01
Average Water Surface	3.81	2.48	1.38	1.39
Mean Daily Low Water, (MLW)	2.58	0.91	-0.44	-0.33
Minimum Water Surface	1.19	0.35	-0.70	-0.71

3. WETLAND FEASIBILITY

The following objectives guided PWA's water quality facility feasibility assessment for the Knightsen watershed:

1. Improve water quality of stormwater and agricultural tailwaters discharging from Knightsen into the Delta. To the extent possible, facilities should direct discharge away from Rock Slough by discharging to other locations.

2. Improve drainage in the Knightsen watershed. Currently, the Knightsen watershed experiences significant flooding after major rainfall events (Photos 1 through 4), particularly in the vicinity of the Delta Road and Byron Highway intersection. Where feasible, drainage improvements should be made to route runoff from developed land to water quality facilities to reduce flood hazards.

The creation of wildlife habitat and passive recreation opportunities such as bird watching may enhance the value of the project, to the extent they can be incorporated into the design in a way that is consistent with objectives 1 and 2.

PWA's feasibility assessment considered the design constraints inherent in the Knightsen area, as described in the following section.

3.1 DESIGN CONSTRAINTS

PWA has identified several design constraints for developing water quality facilities specific to the Knightsen watershed. These constraints include the locally flat slope and low ground elevations, high tidal elevations in the receiving sloughs especially during significant storms, a high local groundwater table, and limitations of the existing drainage network. Each of these constraints is examined below.

3.1.1 Local Ground Elevations

Because ground elevations adjacent to the slough channels at many locations are at or below sea level, water can only be drained from these areas at low tides or by pumping. To the extent possible, locating treatment facilities at higher ground elevations will allow gravity drainage of treated water during a wider range of tidal conditions and preclude or reduce the requirement for pumping. Nonetheless, water quality facilities can be located at lower elevations if the system were designed such that large storms could bypass facilities located at lower elevations and discharge directly to No Name Slough. In this case, treated water would be stored until tidal/flood waters recede and the facility is able to drain to the slough.

In either case, the flat topography in the area slows water flows and makes it difficult to efficiently store large amounts of water without significant excavation or construction.

3.1.2 Tidal Elevations

This study assumes that water quality facilities within the Knightsen watershed will primarily discharge to No Name Slough. Such facilities will only be able to drain by gravity flow when the water level in the slough is lower than the water level in the facility. During small, frequent storms, water quality facilities will detain stormwater runoff and release it slowly in order to remove pollutants. During larger storms, runoff will discharge directly to the slough, either bypassing the facility or passing through without detention. During a storm, water levels in the slough may be elevated by tides, storm surge and runoff, and water quality facility designs will need to account for a variety of tailwater conditions in order to assure that the facility will drain properly.

3.1.3 Groundwater Elevations

Groundwater depth can impact water quality facilities in two ways. Shallow groundwater can limit the effective storage capacity of water quality facilities that are constructed by excavating below ground surface. However, shallow groundwater can also provide a water source for a permanent pool within a wet pond or constructed treatment wetland during dry periods.

3.1.4 Existing Drainage Network

Undersized culverts and ditches and other limitations of the current drainage network prevent stormwater from being efficiently removed from developed and cultivated land. Drainage system improvements could reduce existing flood hazards and also help deliver water to potential water quality facilities. This issue is further discussed in Section 4.

3.2 TREATMENT CONTROL BMP OPTIONS

Four types of storm water quality facilities were considered for the Knightsen project: constructed treatment wetland, extended detention basin, wet pond, and biofilter swale. These are described below and presented in Figure 3. These facilities are considered best management practices (BMPs) for storm water quality treatment control, and are described in detail in the Stormwater Quality Task Force BMP Handbook (SQTF, 1993). All four approaches assume that the facility is designed to treat runoff from smaller, frequent storms, while runoff from larger events will either bypass the facility or "pass through" it (with reduced treatment). The primary water quality treatment mechanism utilized by these facilities is quiescent settling of suspended sediments. Dissolved contaminants including phosphorous and metals are primarily removed through physical adsorption to bottom sediments and suspended fine sediments and uptake by aquatic plants.

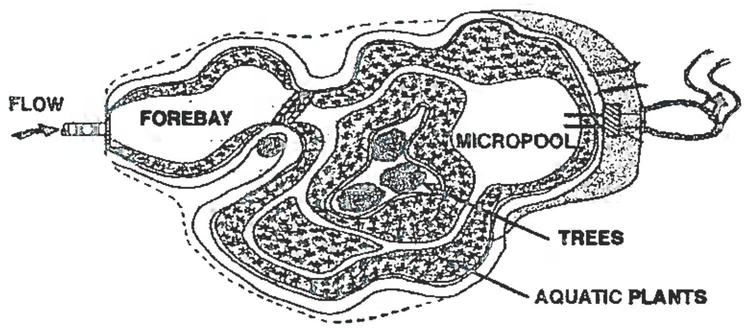
figure 3

Knightsen Project

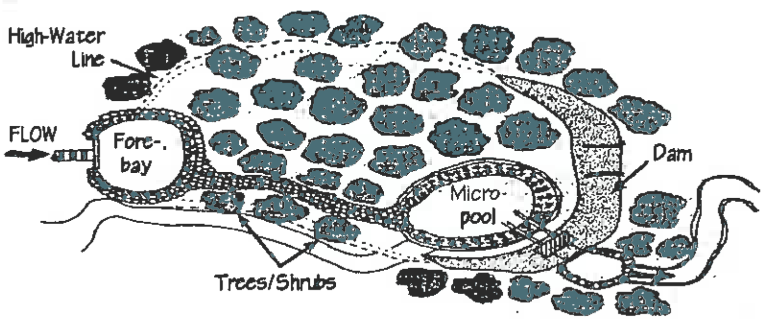
Treatment Control BMP Options

Source: SWQTF, 1993

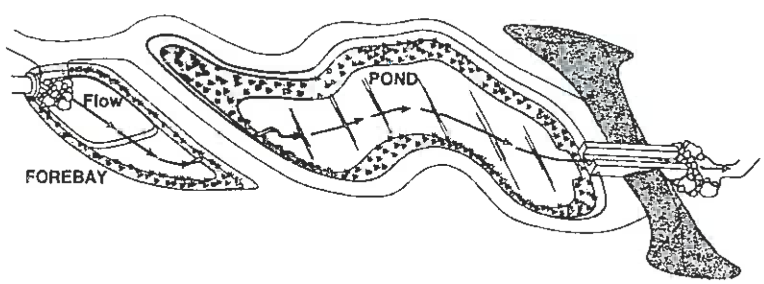
Project#1565 Options.cdr PWA



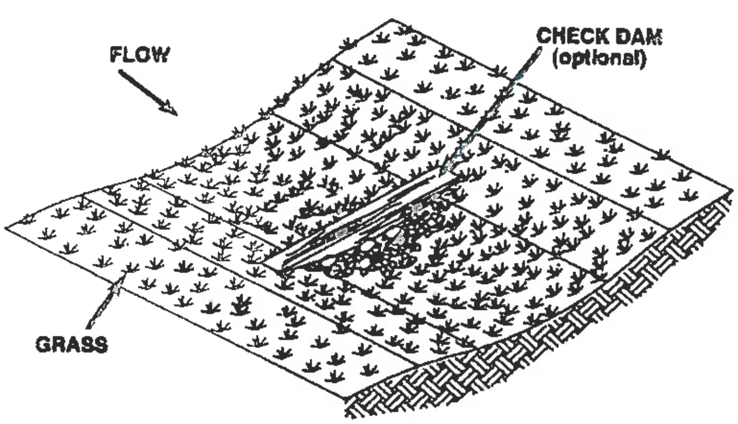
Constructed Treatment Wetland



Extended Detention Basin



Wet Pond



Biofilter Swale

3.2.1 Constructed Treatment Wetland

Constructed treatment wetlands are built specifically for the treatment of storm water runoff. As compared to a wet pond, the constructed wetland is generally shallower with a greater surface area and a greater percentage of vegetated cover. The constructed wetland can incorporate a low flow channel and small permanent pool. Wetland vegetation rooted throughout the constructed wetland improves the removal of dissolved contaminants. Constructed wetlands can also be aesthetically appealing and beneficial to wildlife. Constructed wetlands can achieve a relatively high level of particulate removal similar to a wet pond. Removal of dissolved contaminants, particularly nutrients and metals, should be enhanced as compared to a wet pond.

3.2.2 Extended Detention Basin

An extended detention basin is generally dry between storms. The basin fills during storms and slowly discharges detained water. Extended detention basins are ideal where a lack of perennial base flow or irrigation water precludes the use of wet ponds, constructed wetlands, or biofilters. Extended detention basins are suitable for any size tributary watershed. However, extended detention basins may be less reliable than other treatment control BMP's due to difficulties designing and installing an appropriate outlet structure. Properly designed extended detention basins may remove 60 to 80% of incoming particulates. With a drawdown time of 40 hours, larger clay particles can settle out of suspension. With proper irrigation to maintain healthy vegetation on the basin floor, extended detention basins can remove dissolved contaminants at least as well as biofilter swales discussed below.

3.2.3 Wet Pond

A wet pond is essentially a small pond with rooted wetland vegetation along the perimeter that utilizes a permanent pool to treat incoming storm water. Between storms, the permanent pool provides a quiescent storage area for the settling of particulates and uptake of dissolved contaminants by aquatic plants. The wetland vegetation rooted along the perimeter of the pond improves the removal of dissolved contaminants and reduces the formation of algal mats. Wet ponds can achieve a relatively high level of particulate removal and some dissolved contaminant removal, particularly nutrients and metals.

3.2.4 Biofilter Swale

A biofilter swale is a wide, shallow vegetated channel designed to maintain low flow velocities and keep the flow depth below the height of the vegetation for a design discharge. The swale bottom should be wide and level. Energy dissipation and a flow spreader may be utilized at the entrance to prevent channelization. The swale is normally vegetated with a turf grass which requires irrigation during the late summer and early fall to ensure the vegetation is healthy prior to the first storms. Check dams can be utilized to form a series of terraces to further reduce flow velocities and minimize channelization. As compared to wet ponds and constructed wetlands, which provide treatment both during and between storms, the biofilter swale will probably be less effective at removing particulate and dissolved contaminants.

3.3 BMP RECOMMENDATIONS

Given the objectives and design constraints described above, PWA briefly evaluated the BMPs introduced in the previous section, and developed a conceptual plan for implementation of BMP facilities.

- Constructed treatment wetlands are well suited to the flat slopes in the Knightsen watershed. The existing topography and groundwater table could accommodate the shallow depths utilized in a constructed wetland facility. Wetlands could be supported by ECCID tailwater during the summer months.

- Extended detention basins could also be designed to accommodate local conditions. Because extended detention basins are designed to dry out between storm events, the need for irrigation and/or baseflow to maintain a permanent pool is limited.

- Wet ponds may not be well suited to the Knightsen watershed because the deep permanent pool required in a wet pond design would require either significant excavation or construction of levees above existing ground surface. The shallow groundwater table may be limit excavation.

- Biofilter swales may not be well suited for much of the Knightsen watershed because the extremely flat slopes require an exceedingly wide biofilter swale to accommodate runoff from larger sub-watersheds. However, some benefits of the biofilter swale concept could be realized by utilizing wide, shallow channels as opposed to narrow, deep channels for drainage improvements and bypass channels where possible. Also, where contributing areas are small and runoff volumes are low, biofilter swales could be utilized for conveying runoff to water quality facilities or directly to a receiving slough.

Either constructed treatment wetlands or extended detention basins could meet the objectives of this project. The most appropriate water quality facility designs may include a combination of constructed treatment wetland and extended detention basin features. For example, facilities could be sized as extended detention basins and designed to include features of constructed treatment wetlands. The facilities could be relatively dry during the summer and fall, depending on the amount of irrigation runoff available. The facility design could also include a series of constructed wetlands designed to both improve drainage and address water quality issues by providing water quality treatment during low flows while providing sufficient capacity to convey larger storms.

3.3.1 Sizing

PWA developed a preliminary estimate of the volume of water that would need to be captured and stored in order provide BMP treatment for runoff from each sub-watershed area. This "capture volume" was based on watershed area, land use parameters, and a design storm. PWA then estimated the size of the water quality facilities that would be required, assuming the estimated capture volume and a certain duration of storage and treatment. Based on this design approach and guidance provided in the Stormwater Quality Task Force Handbook ("Handbook"; SWQTF, 1993), PWA used the following assumptions and parameters to estimate the size of BMP facilities included in the conceptual implementation plan.

- unit storage volume of 0.018 acre-feet per acre of contributing watershed area;
- 40-hour detention/drawdown time for water treatment;
- directly connected impervious area (DCIA) of 12% for residential and agricultural land with average lots greater than 2 acres;
- capture goal of 90% of average runoff.

Results are presented in Table 5.

Table 5. Estimated Water Quality Volume (WQV) Summary

Watershed	Area (acres)	WQV (acre-feet)
WS#1: Northwest Knightsen	396	7.1
WS#2: Northeast Knightsen	950	17.1
WS#3: Central Knightsen	321	5.8
WS#4: Tule Lane	684	12.3
WS#5: Southwest Knightsen	1537	27.7
WS#6: South Knightsen	1146	20.6
WS#7: Delta Road	189	3.4
WS#8: Byron Highway	235	4.2
WS#9: Veale Tract	473	8.5
WS#10: Southeast Knightsen	875	15.8
Total	**6806**	**122.5**

Considering the extremely flat topography of the Knightsen watershed, an average depth of 1 to 2 feet for a water quality treatment facility is reasonable, as a deeper facility would require extensive excavation or levees. Therefore, approximately 61 to 122 acres of land devoted to water quality facilities would be required to provide BMP water quality treatment for the entire Knightsen watershed. The design guidelines for treatment wetlands provide a "rule of thumb" estimate of 1 to 2% of total tributary watershed area for constructed treatment wetlands. Using this guideline, the 6806-acre Knightsen watershed would require wetlands with a surface area of 68 to 136 acres, which is consistent with the water quality volume estimate.

3.3.2 Conceptual Implementation Plan

Given the relatively flat slopes in the Knightsen watershed and the natural tendency of the area to drain as sheet flow and in shallow channels towards the Delta, collecting the runoff from the entire watershed into a single water quality facility will be difficult. Therefore, PWA divided the Knightsen watershed into four smaller areas as shown in Figure 4: Northern Knightsen, Central Knightsen, Southwest Knightsen, and Southeast Knightsen; and examined options for each area for water quality facilities for small, frequent storms and related bypass channels or "pass through" capacity for larger storms.

Table 6. Estimated Water Quality Volume (WQV) by Area

Watershed	Area (acres)	WQV (acre-feet)
Northern Knightsen (WS#1, #2)	1346	24.2
Central Knightsen (WS#4, #7, #8, #9)	1581	28.4
Southwest Knightsen (WS#3, #5, #6)	3004	54.1
Southeast Knightsen (WS#10)	875	15.8

3.3.2.1 Northern Knightsen

The combined water quality volume estimate for the Northwest and Northeast Knightsen sub-watersheds is 24 acre-feet, requiring approximately 12 to 24 acres of land devoted to water quality treatment. Given the distance of these sub-watersheds from No Name Slough, routing runoff across the naturally flat surface gradient to No Name Slough would be difficult. Therefore, PWA recommends consideration of a more proximate discharge point for this area. The Jersey Island Ditch, which currently drains the Dutch Slough Gas Field and portions of northern Knightsen and discharges to Sand Mound Slough, would be a more hydraulically efficient receiving slough for the discharge from north and northeastern Knightsen.

A water quality treatment facility located in the vicinity of the Jersey Island ditch south of Cypress Road could provide water quality and drainage benefits for northern Knightsen as shown on Figure 4. Ditches could be located south of Cypress Road and south of the Contra Costa Canal to convey runoff to the treatment facility. Water quality benefits could be maximized if the ditches were designed as biofilter swales conveying runoff to a series of treatment wetlands that discharge to the Jersey Island ditch. Or, if land-use constraints make biofilter swales or a series of wetlands impractical, a more traditional ditch design could be used, discharging to larger treatment wetlands on either side of the Jersey Island ditch.

PWA estimated that a facility located on land with an existing ground surface elevation of 4 to 5-feet NGVD would discharge via gravity to Jersey Island ditch. Ground elevations in this area are high enough that the facility could be designed for either "pass through" or bypassing of larger storms.

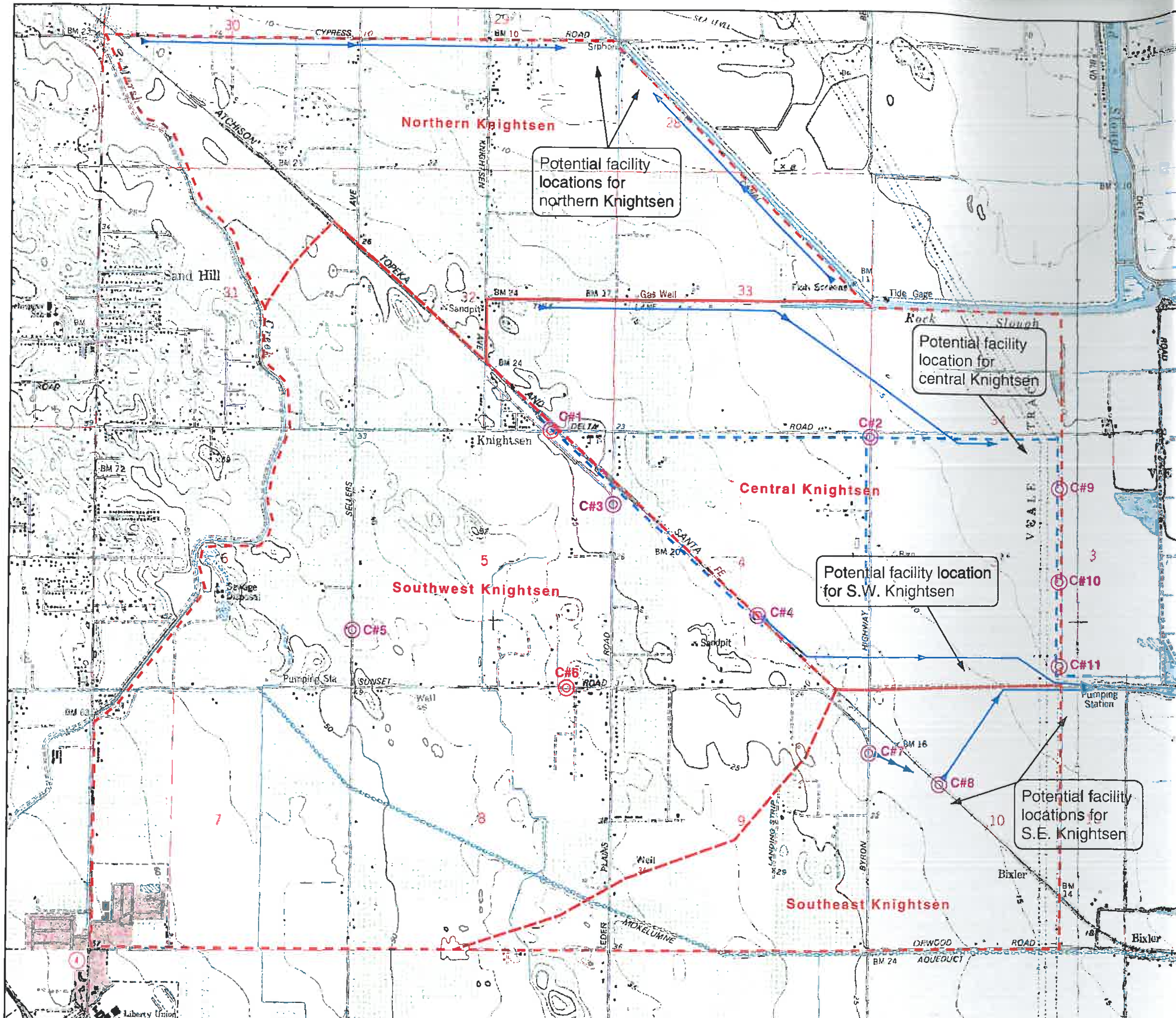


figure 4

Knightsen Project

Knightsen Project Site

Project#1565 knight-newF4vx.mxd

PWA

LEGEND

Sub-Watershed

Existing Culvert

Existing Ditch

Possible Drainage or Biofilter Swale Locations

N

0 1,250 2,500 5,000

Feet

3.3.2.2 *Central Knightsen*

The Central Knightsen area includes the Tule Lane, Delta Road, Byron Highway, and the Veale Tract sub-watersheds (Figure 4). The combined water quality volume estimate for this area totals 28 acre-feet and requires approximately 14 to 28 acres of land devoted to water quality treatment.

The Central Knightsen area includes potential seasonal wetland habitat observed on the Veale Tract south of Delta Road near the PG&E easement (Photos 10 through 12). This potential seasonal wetland area is located at the lowest point in the Knightsen watershed and is the natural destination for runoff from eastern Knightsen. This area could be expanded and enhanced to be the primary water quality facility for Central Knightsen. An existing channel currently conveys runoff from Delta Road past the potential seasonal wetland area to No Name Slough. This channel could be utilized to route discharge from a water quality facility to No Name Slough.

The Delta Road, Byron Highway, and Veale Tract sub-watersheds all discharge towards the potential seasonal wetland area. New drainage facilities would be required in the Tule Lane sub-watershed in order to route runoff from that sub-watershed across Delta Road to the seasonal wetland area as shown on Figure 4. Alternatively, one or more facilities could be developed north of Delta Road to provide treatment for runoff from the Tule Lane sub-watershed, and a ditch or swale could be constructed to route discharge across Delta Road to the ditch along the PG&E easement and on to No Name Slough.

Surface elevations in the potential seasonal wetland area south of Delta Road near the PG&E easement range from 0.5- to 1-feet NGVD. Therefore, a water quality treatment facility in this area would drain via gravity flow to No Name Slough only when water levels in No Name Slough were near or below average levels. During significant storms or high tides, the facility would need to store treated water until tidal/flood waters recede and water levels in the slough return to average levels. The facility could be designed so that larger storms bypass the facility directly to the ditch along the PG&E easement. However, due to the low surface elevations throughout eastern Knightsen, extreme storms may submerge both the bypass channel and water quality facility until tidal/flood waters recede.

3.3.2.3 *Southwest Knightsen*

The Central, South, and Southwest Knightsen sub-watersheds combine at the culvert crossing the Santa Fe railroad tracks north of Sunset Road (C#4) as shown on Figure 4. Based on PWA's hydrologic assessment (Chapter 2), the majority of the runoff that enters the "Knightsen Triangle" between Byron Highway and Delta Road passes through this culvert. Therefore, diverting flow from culvert C#4 directly to water quality facilities and eventually to No Name Slough will tend to reduce flood hazards in the "Knightsen Triangle." A wide, shallow, vegetated diversion channel to convey water from this culvert eastward across Byron Highway toward Veale Tract would also help to maximize water quality benefits. Earlier studies have also recommended a diversion channel in this location (Mattern & Associates, 1998 and CCCFCWCD, 1985).

The estimated water quality volume for the combined Central, South, and Southwest Knightsen sub-watersheds is 54 acre-feet, requiring approximately 27 to 54 acres of land devoted to water quality treatment. The required water quality capacity could be provided on Veale Tract either at higher elevations near Byron Highway as shown on Figure 4, or combined with a facility addressing runoff from eastern Knightsen located at lower elevations south of Delta Road. Locating a water quality treatment facility at higher elevations would assure that the facility could drain via gravity flow to No Name Slough under most tidal and storm conditions. However, if the amount of available land is a significant constraint, it may be more desirable to route runoff to the lower elevations near Delta Road and provide a combined facility for the Southwest and Eastern Knightsen watersheds at this location. In either case, the diversion channel from Southwest Knightsen could terminate in a diversion forebay east of Byron Highway that would route smaller storms into the treatment facility and larger storms directly to No Name Slough. The forebay could also provide pretreatment, trapping floatable debris and larger settlable solids, facilitating maintenance and protecting wetland vegetation in the treatment facility.

3.3.2.4 Southeast Knightsen

catherine

The estimated water quality volume for the southeast Knightsen watershed is 16 acre-feet requiring 8 to 16 acres of land devoted to water quality treatment. As seen in Photo 1, flooding currently occurs behind the culvert that crosses the railroad tracks just south of Sunset Road (C#8). Ponding of floodwaters in this area likely provides some water quality benefit, and this natural collection point could be developed into a water quality facility.

PWA estimates that approximately 50% of the runoff from Southeast Knightsen passes through culvert (C#8), so a facility at this location as shown on Figure 4 could treat a portion of the runoff from Southeast Knightsen. Ground elevations in this area are approximately 15- to 16-feet NGVD, so the facility could discharge by gravity flow via an outlet channel directly to No Name Slough.

Alternatively, if land-use issues prevent locating a facility southwest of culvert C#8, the water treatment capacity required for Southeast Knightsen could be provided in a separate facility southwest of No Name Slough as shown on Figure 4. It may also be possible to route flows from Southeast Knightsen to the diversion channel recommended for Southwest Knightsen.

4. DRAINAGE NETWORK

PWA performed site reconnaissance and field surveys to help characterize the project area and to assess the ability of the existing drainage network to deliver water to potential water quality facilities at the downstream end of the drainage area. As a result of this assessment, we developed recommendations for improvements to the drainage network to both support implementation of water quality BMPs and help improve stormwater drainage.

Storm drain systems are customarily designed to convey the peak discharge from a 10- to 25-year rainfall event. Given the limited existing drainage network, PWA considered the 10-year event to be a reasonable design storm to use in making recommendations for drainage improvements. Depending upon available funding, the community may choose to use a lesser design storm, or to implement selected improvements to provide the greatest reduction of flood hazards with limited funding.

4.1 EXISTING INFORMATION

PWA's primary sources for information regarding topography in the Knightsen area were the USGS 5'-contour topographic maps of the Brentwood and Woodward Island quadrangles (USGS, 1978), and Knightsen/Brentwood 2' contour topographic drainage maps provided by Contra Costa County Public Works Department.

The *Knightsen – Drainage Improvement Assessment* (Mattern and Associates, 1998) provided additional detail regarding topography and infrastructure in the Knightsen area, including a description of the major culverts in the drainage network:

- 21" concrete culvert – moves water from west across Sellars Avenue north of Sunset Road. Discharge spreads across properties east of Sellars Avenue as sheet flow.
- 18" CMP – moves water across Eden Plains Road just south of the railroad tracks.
- 21" concrete culvert – moves water from south to north across Sunset Road at S. Cumming Road west of Eden Plains Road.
- 24" culvert – moves water from central Knightsen south across Delta Road just west of railroad tracks.
- 30" wide x 38" high box formed with railroad ties – moves water across railroad tracks north of Sunset Road and west of Byron Highway. Further south there are two 24" cmps located higher above ground.

4.2 PWA SURVEYS

PWA visited Knightsen on January 3, 2002 following several significant rainfall events and observed minor flooding at several locations throughout the drainage area including:

- the intersection of Curlew Connex and Delta Road,
- the intersection of Delta Road and Byron Highway (Photos 5 through 7), and
- along Byron Highway near Iron Horse Road (Photos 8 and 9).

Based on PWA's site reconnaissance, the following factors appeared to contribute to the flooding along Byron Highway at the intersections of Delta Road and Iron Horse Road:

- undersized and partially blocked culverts,
- undersized drainage ditches, and
- local highpoints in drainage ditches.

In order to help characterize limitations in the existing drainage network observed during site reconnaissance, PWA performed a field survey which is described in the following sections.

4.2.1 Profile and Cross-Section Surveys

PWA performed a field survey of the slopes and cross sections of existing drainage features. This survey was designed to estimate the capacity of various existing drainage ditches and culverts along the primary drainage network along Delta Road and Byron Highway. Fifteen drainage ditch cross sections were surveyed along Delta Road, Byron Highway, and the PG&E easement on the Veale Tract in locations shown on Figure 5. The locations are shown on Figure 5 and plots of individual cross sections are presented in Appendix C.

- Delta Road between the railroad tracks and Byron Highway, surveyed cross sections 1 through 4 illustrate a modest drainage ditch on the south side of Delta Road, approximately 11 feet wide and 2 feet deep at the intersection of Byron Highway.

- Byron Highway between the railroad tracks and Delta Road, cross sections 13 through 15 illustrate a modest drainage ditch on the west side of Byron Highway, approximately 12 feet wide and 1.5 feet deep at the intersection of Delta Road.

- Delta Road between Byron Highway and the PG&E easement on Veale Tract, cross sections 6 through 8 illustrate a well-defined drainage ditch on the south side of Delta Road, approximately 6 to 15 feet wide and 1.6 to 2.6 feet deep.

- Along the PG&E easement on the Veale Tract between Delta Road and No Name Slough, cross sections 9 through 12 illustrate a large drainage ditch (approximately 25 feet wide and 3 to 6 feet deep) on the east side of the PG&E easement on the Veale Tract.

Drainage ditch channel profiles were surveyed along the south side of Delta Road from Peach Tree Lane to the PG&E easement on the Veale Tract, the west side of Byron Hwy from the railroad tracks to Delta Road, and the east side of PG&E easement from Delta Road to No Name Slough. Culvert size, condition and elevation were noted along each profile. Local high points at certain culverts were identified in each ditch profile. Plots of the drainage ditch profiles are presented in Figures 6 and 7.

The drainage ditch on the south side of Delta Road has a slope of 0.35% between Eden Plains Road and Byron Highway and 0.14% between Byron Highway and the PG&E easement. The drainage ditch on the west side of Byron Highway has a slope of 0.18% between Iron Horse Road and Delta Road. Numerous culverts were identified along Delta Road and Byron Highway that cause local breaks in slope. The drainage ditch east of the PG&E easement has a slope of 0.01% between Delta Road and No Name Slough.

4.2.2 Drainage Ditch Capacity

Drainage ditch capacity was estimated at each surveyed cross section location presented on Figure 5. Conveyance capacity was computed with Manning's equation using survey data including channel cross section and slope:

$$Q = 1.486/n\ R^{2/3}\ S^{1/2}\ A$$

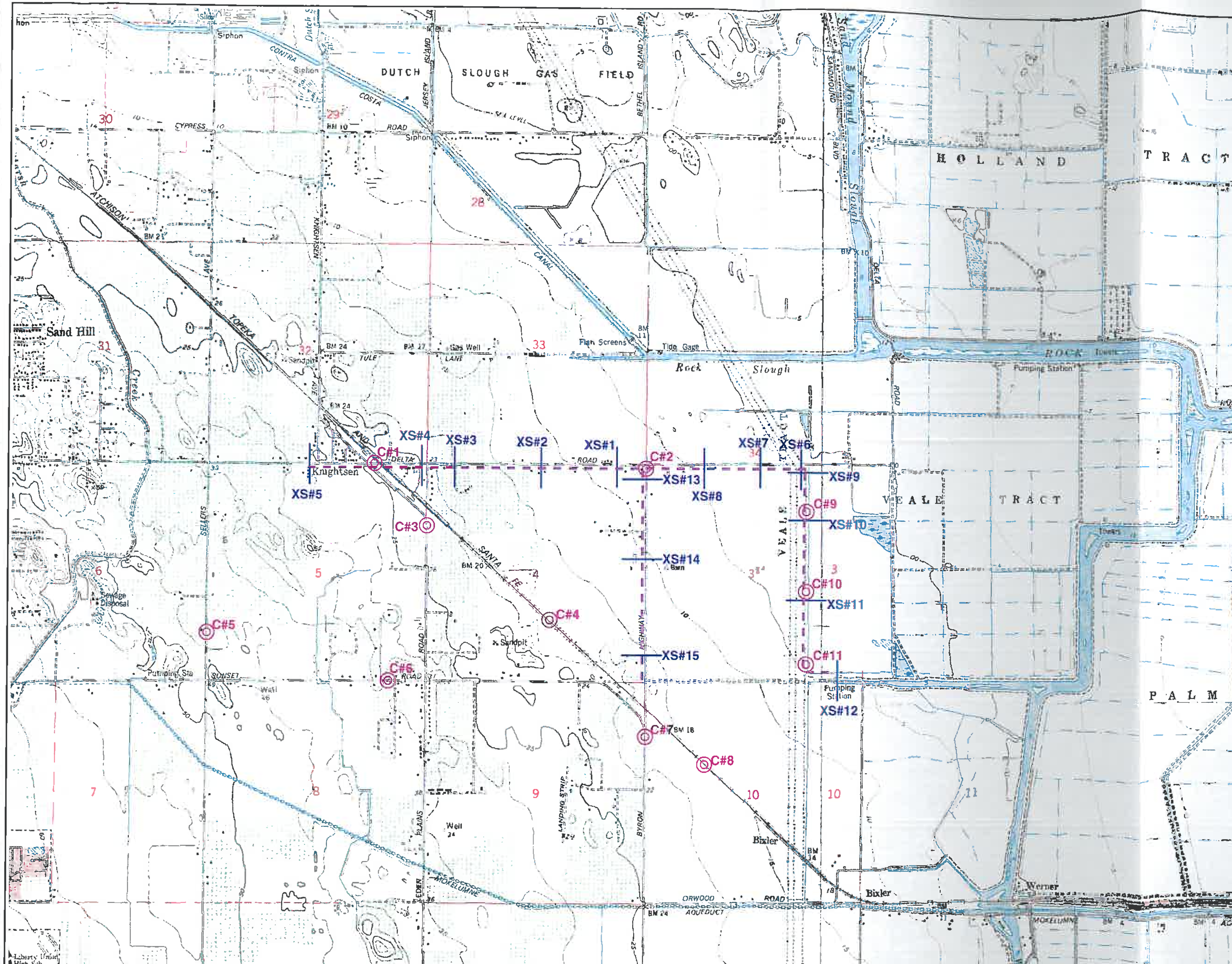
where n is Manning's n, R is hydraulic radius in feet, S is channel slope feet/foot, and A is channel cross-sectional area. Ditch slopes and cross sections were estimated from survey data, and a Manning's *n* value for small drainage ditches was selected (Haan et al., 1994).

figure 5

Knightsen Project

Surveyed Profile and Cross-Section Locations

Project#1565 knight4.mxd PWA



LEGEND

Culvert

Cross-Section

Surveyed Profile

(cross-sections shown represent location, not length)

N

0 2,000 4,000

Feet

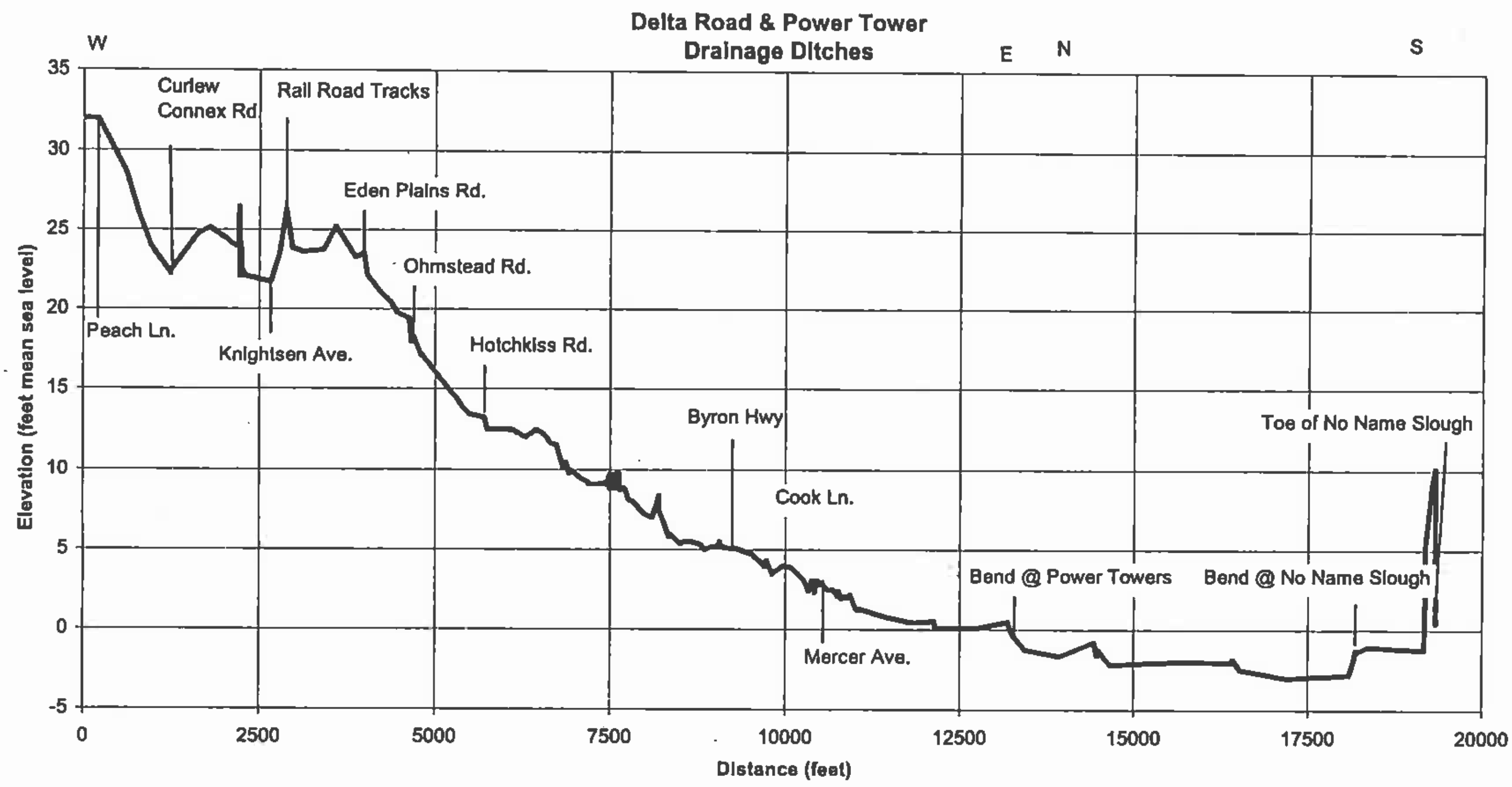


Figure 6: Knightsen Topography

Drainage Ditch Profile
South Side of Delta Road
and East of Power Towers

PWA

PWA#: 1565

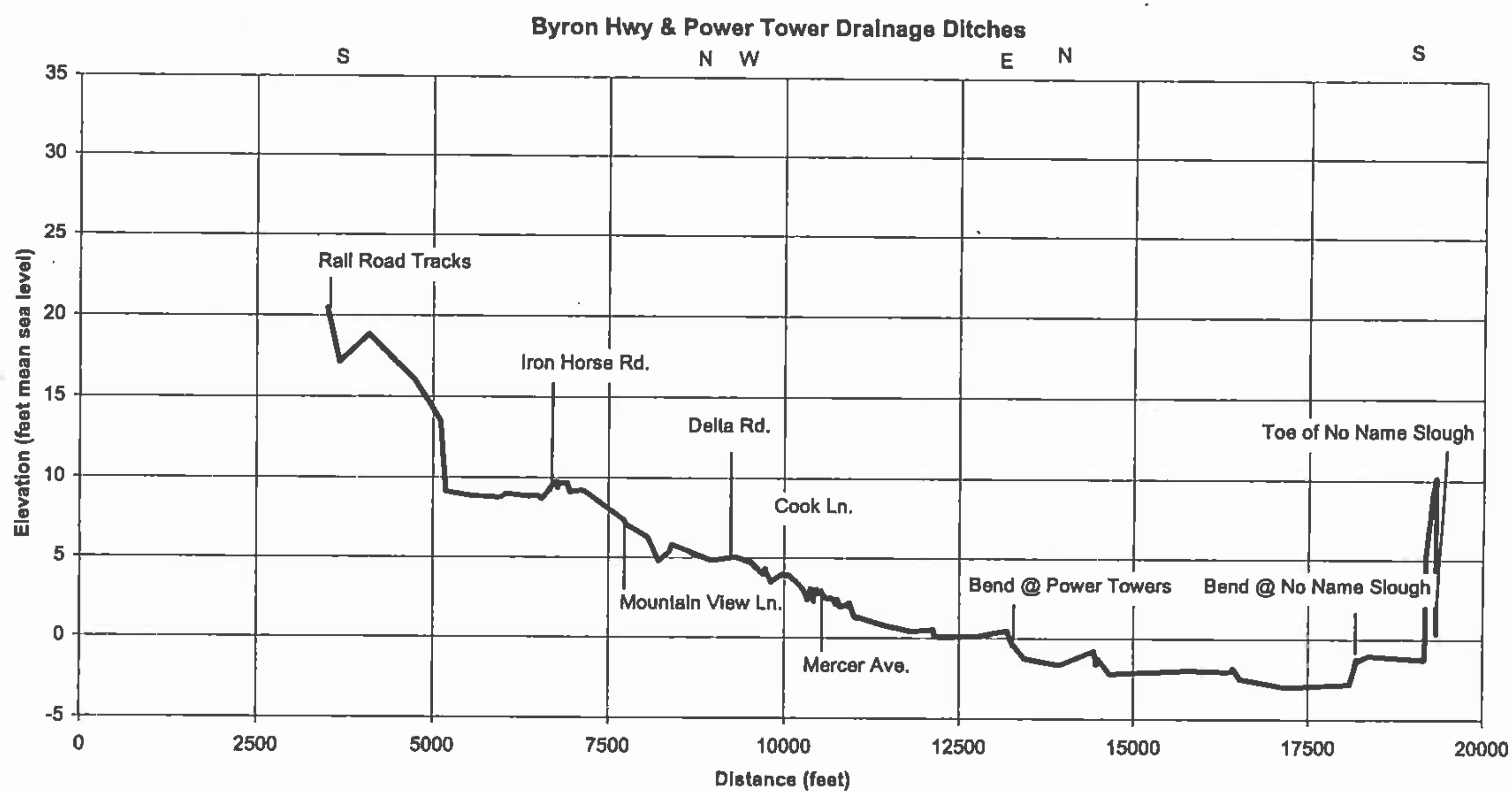


Figure 7: Knightsen Topography

Drainage Ditch Profile
West Side of Byron Hwy, South Side of Delta Road and East of Power Towers

PWA | PWA#: 1565

Drainage ditch capacity estimates are presented in Appendix F and summarized below in Table 7. Also included in Table 7 and Appendix F, are estimates of the 10-year peak discharge as discussed in Section 2.2.1.2.

Table 7. Estimated Drainage Ditch Capacity

Cross Section & Location	Width (feet)	Depth (feet)	Slope	Capacity (cfs)	10-year Peak Q (cfs)
XS 5: Delta Road west of Knightsen Ave.*	0	0	0.35%	0	30
XS 4: Delta Road west of Eden Plains Road	12.5	0.5	0.35%	3.1	2
XS 3: Delta Road east of Eden Plains Road*	0	0	0.35%	0	4
XS 2: Delta Road bet. Eden Plains Road & Byron Hwy.	11.2	1.5	0.35%	17.1	13
XS 1: Delta Road west of Byron Highway	10.8	2.3	0.35%	32.3	19
XS 15: Byron Highway north of Sunset Road *	0	0	0.50%	0	4
XS 14: Byron Highway bet. Sunset Road & Delta Road	16.4	2.5	0.02%	12.4	169
XS 13: Byron Highway south of Delta Road	12.1	1.5	0.18%	12.9	169
XS 8: Delta Road east of Byron Highway	5.9	1.6	0.14%	6.1	179
XS 7: Delta Road bet. Byron Hwy. & PG&E ditch	15.1	2.6	0.14%	35.4	179
XS 6: Delta Road west of PG&E ditch	9.8	2.4	0.14%	19.5	179
XS 9: PG&E ditch south of Delta Road	24.4	3.0	0.01%	38.3	179
XS 10: PG&E ditch bet. Delta Road & No Name Slough	24.9	5.4	0.01%	97.1	179
XS 11: PG&E ditch north of No Name Slough	24.0	5.7	0.01%	101.3	179
XS 12: PG&E ditch west of bend @ No Name Slough	45.9	5.9	0.01%	219.5	179

* Drainage ditch dimensions of "0" indicate that there is no defined ditch at this location.

A comparison of drainage ditch capacity estimates to 10-year peak discharge estimates indicates:

- The drainage ditch along Delta Road between the railroad tracks and Byron Highway can contain 100% of the estimated 10-year peak discharge from WS#7.

- The drainage ditch along Byron Highway between the railroad tracks and Delta Road can contain less than 10% of the estimated 10-year peak discharge from WS#3, WS#5, WS#6, and WS#8 combined (Central, Southwest, and South Knightsen, and Byron Highway sub-watersheds).

- The drainage ditch along Delta Road between Byron Highway and the PG&E easement on the Veale Tract can contain up to approximately 20% of the estimated 10-year peak discharge from WS#3, WS#5, WS#6, WS#7, and WS#8 combined.

- The drainage ditch along the PG&E easement on the Veale Tract cannot fully contain the estimated 10-year peak discharge from WS#3, WS#5, WS#6, WS#7, WS#8, and WS#9 combined. However, due to the limited capacity in the drainage network upstream, this drainage ditch is not likely to receive the full peak discharge from upstream under current conditions.

4.2.3 Culvert Capacity

PWA estimated the capacity of several key culverts located throughout the Knightsen drainage area. These culverts are identified on Figure 5. Full culvert discharge capacity was computed with Manning's equation using survey data including culvert cross-section and slope:

$$Q = 1.486/n\, R^{2/3}\, S^{1/2}\, A$$

where n is Manning's n, R is hydraulic radius in feet, S is channel slope feet/foot, and A is culvert cross sectional area. Ditch slopes and culvert sizes were estimated from survey data, and Manning's *n* values for concrete and corrugated metal culverts were selected from a published text (Haan et al., 1994).

Culvert capacity estimates and the associated variables used in the calculations are presented in Appendix F and summarized below in Table 8. Culvert capacity estimates included in Table 8 assume that the entire flow area of the culvert is available to transfer flow, neglecting the effects of deposited sediment or damaged culverts. Estimates of the 10-year peak discharge, as discussed in Section 2.2.1.2, are also included in Table 5.

Table 8. Estimated Culvert Capacity

Culvert Location	Culvert Size	Slope	Capacity (cfs)	Estimated 10-year Peak Q (cfs)
C#1: Delta Road @ Sante Fe railroad tracks	24-inch dia.	0.01%	1.2	33
C#3: Eden Plains Road south of Delta Road	18-inch dia.	0.33%	3.2	111
Delta Road bet. Eden Plains Road & Byron Hwy.	12-inch dia.	0.35%	1.4	5
Delta Road bet. Eden Plains Road & Byron Hwy.	24-inch dia.	0.35%	8.7	12
C#4: Sante Fe railroad tracks north of Sunset Road	2.5 x 3.2-feet	0.33%	35.6	181
Byron Highway bet. Sunset Road & Delta Road	10-inch dia.	0.18%	0.6	169
Byron Highway bet. Sunset Road & Delta Road	18-inch dia.	0.18%	1.9	169
C#2: Delta Road @ Byron Highway	30-inch dia.	0.14%	7.9	179
Delta Road bet. Byron Hwy. & PG&E ditch	10-inch dia.	0.14%	0.5	179
Delta Road bet. Byron Hwy. & PG&E ditch	32-inch dia.	0.14%	11.8	179
PG&E ditch bet. Delta Road & No Name Slough	60-inch dia.	0.01%	20.0	179

A comparison of culvert capacity estimates to 10-year peak discharge estimates indicates that culverts throughout the Knightsen drainage area are undersized as compared to the estimated 10-year runoff and are likely a limiting factor impeding drainage in the area. Specifically, at some key culverts the following conclusions can be drawn:

- The culvert that crosses the railroad tracks north of Sunset Road, C#4 as shown on Figure 5, has the capacity to transfer approximately 20% of the estimated 10-year peak discharge from WS#3, WS#5, and WS#6 combined (Central, Southeast, and South Knightsen).

- The 30-inch diameter culvert on Delta Road at the corner of Byron Highway, C#2 as shown on Figure 5, is significantly undersized as compared to the estimated 10-year peak discharge from WS#3, WS#5, WS#6, WS#7, and WS#8 combined.

- Driveway culverts along Byron Highway and Delta Road are significantly undersized compared to the estimated combined 10-year peak discharge from the contributing watersheds.

- The 60-inch culverts in the drainage ditch west of the PG&E easement, C39, C#10, and C#11 as shown on Figure 5, only have an estimated capacity of 20 cfs, primarily due to the extremely flat slope of this drainage ditch. This compares to an estimated combined 10-year peak discharge from WS#3, WS#5, WS#6, WS#7, WS#8, and WS#9 of 179 cfs. However, due to the undersized culverts up-gradient from this ditch, this ditch probably never receives the full discharge from the up-gradient watershed.

PWA's assessment of the capacity of the existing drainage network indicates that undersized culverts are likely to contribute significantly to the frequent flooding in the Knightsen area. In addition, limitations in the drainage network limit the ability for runoff to be delivered to any potential water quality facilities that may be located at the downstream end of the drainage area.

4.3 DRAINAGE IMPROVEMENT RECOMMENDATIONS

PWA recommends the following improvements to the existing drainage network shown in Figures 4 and 5 be made in conjunction with implementation of water quality BMP facilities. These changes will improve drainage throughout the watershed and deliver runoff to any potential water quality facilities more efficiently. A longer term goal for Knightsen may be to design storm drain facilities to convey the 10-year peak discharge, and other improvements to protect residences and structures from flood hazards from a 100-year event. The recommended improvements are based on the estimated 10-year peak discharge at each reach considered in the drainage network.

1. Route flows from central and southwest Knightsen directly from the culvert at the railroad tracks north of Sunset Road directly across Byron Highway to water quality facilities and eventually to No Name Slough as shown in Figure 4. This "bypass" would route approximately two-thirds of the runoff that currently enters the "Knightsen triangle" away from the undersized ditches and culverts along Byron Highway and Delta Road east of Byron Highway.

2. The drainage ditch along Delta Road west of Byron Highway as shown on Figure 5 should have sufficient capacity to convey the estimated 10-year peak flow from the Delta Road sub-watershed of 22 cfs. However, larger culverts are needed to convey the estimated 10-year peak flow. Recommended culvert sizes for this ditch range from 12- to 18-inch diameter corrugated metal pipe with estimated capacities of 1 to 3 cfs in the vicinity of the Santa Fe railroad tracks to 30-inch diameter concrete pipe with an estimated capacity of 22 cfs just west of Byron Highway.

3. The capacity of the drainage ditch and culverts along Byron Highway south of Delta Road as shown in Figure 5 should be increased to convey the estimated 10-year peak flow from the Byron Road sub-watershed of 31 cfs after diverting flows passing through culvert at the railroad tracks as discussed above. If the existing 12- to 16-foot wide drainage ditch were excavated to provide a flat base with 2:1 side slopes and flow depths of approximately 1-foot, the ditch would have an estimated capacity of 17 to 31 cfs. Recommended culvert sizes range from 30-inch diameter concrete pipe with an estimated capacity of 16 cfs in the vicinity of Iron Horse Road to 36-inch diameter concrete pipe with an estimated capacity of 26 cfs just south of Delta Road.

4. Along Delta Road from Byron Highway east to the PG&E easement, the capacity of the culverts and drainage ditch as shown on Figure 5 need to be increased to convey the estimated 10-year

peak flow from the combined Delta Road and Byron Highway sub-watersheds of 50 cfs. Given the flat slope along this reach, three 30-inch diameter concrete pipe culverts would provide an estimated capacity of 42 cfs, and two 36-inch diameter concrete pipe culverts would provide an estimated capacity of 46 cfs. If the existing 6- to 15-foot wide drainage ditch were excavated to provide a 15-foot wide ditch along the entire reach with a flat base, 2:1 side slopes and flow depths of 1.3 feet, the ditch would have an estimated capacity of 51 cfs.

5. The ditch along the PG&E easement should have sufficient capacity to convey the estimated 10-year peak discharge from the combined Delta Road, Byron Highway, and Veale Tract sub-watersheds of 74 cfs. However, the culvert discharging flow from this ditch to No Name Slough is significantly undersized. Given the potential for elevated tide levels in No Name Slough related to storm surge and runoff to impede discharge, a 6-foot diameter flap gated culvert is recommended to convey flows from the PG&E ditch into No Name Slough.

5. CONCLUSION

Based on the assessments described in this report, PWA has concluded that it would be feasible to construct treatment control BMPs such as treatment wetlands or wet ponds in the Knightsen area to help improve stormwater and agricultural runoff water quality. The conceptual implementation plan outlined in Chapter 3 of this report identifies potential sites for BMP facilities, and Chapter 4 describes recommended improvements to the existing drainage system to help convey stormwater to BMP facilities and reduce existing flood hazards.

This report concludes Phase I (Task 1) of the Knightsen Wetlands Biofilter Feasibility Study. Phase II of the project will build on this study to refine the wetland concept and provide additional analyses necessary to implement the project. PWA's September 5, 2001 Scope of Work outlines the following tasks for Phase II:

Task 2 – Field Testing and Observation (groundwater and water quality)
Task 3 – Refinement of Wetland Concept, Site Selection, Alternatives Analysis
Task 4 – Assessment of Hydrologic Impacts from Wetland System
Task 5 – Wetland Planning, Permitting and Cost Estimates

As part of Phase II, PWA will refine the BMP design concepts and analyze design alternatives, assess potential hydrologic impacts such as potential changes to FEMA floodplain designations, and identify planning, permitting and cost requirements. The PWA team looks forward to initiating Phase II of this promising project.

6. LIST OF PREPARERS

This report was prepared by the following PWA staff:

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8. PHOTOS 1 TO 12

Photos 1 - 4

Knightsen Project

Flooding during February, 1998

Photo source:
Seth Cockrell, Chair, Knightsen Town Advisory Council

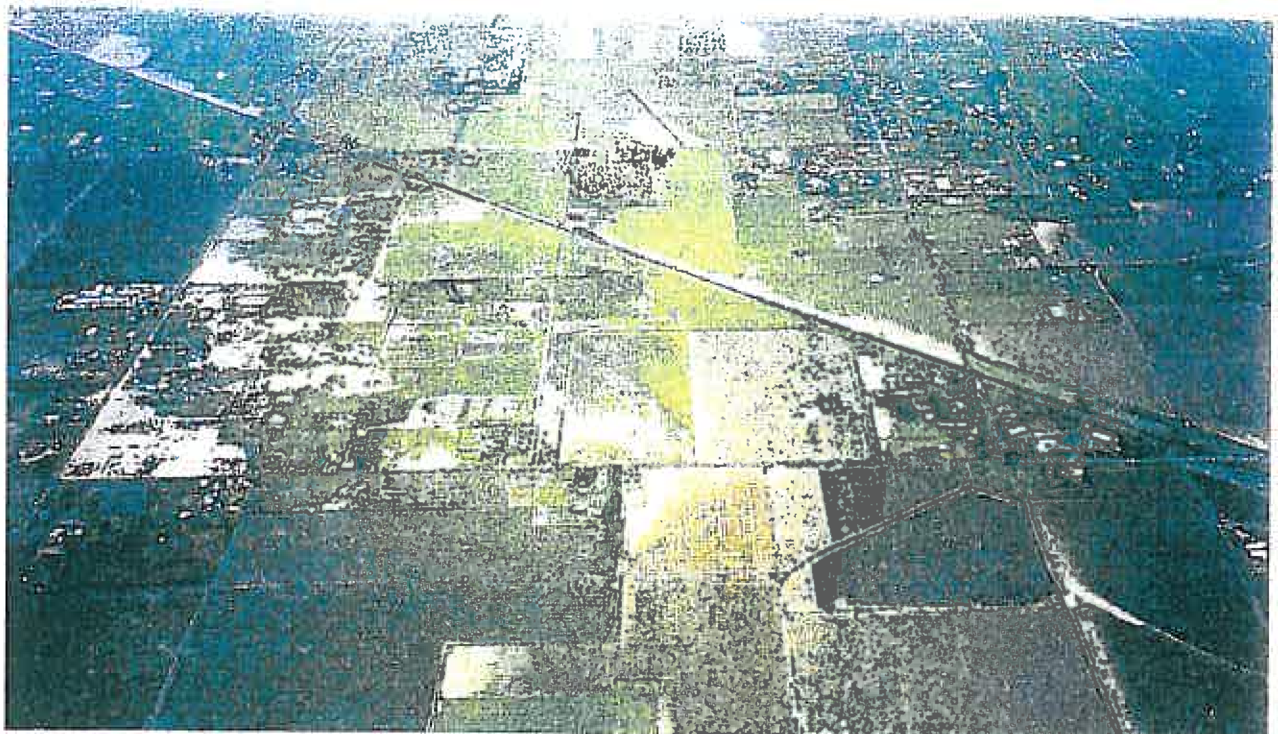


Photo 1

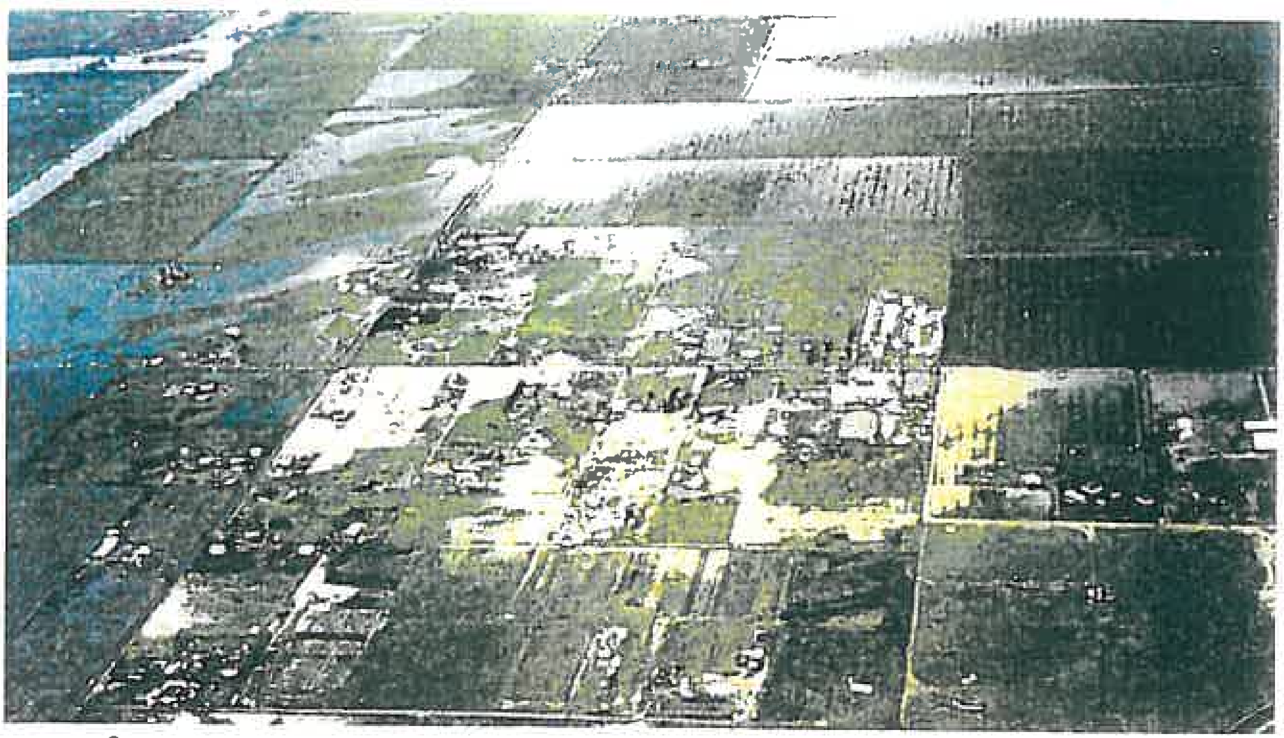


Photo 2

Project#1565 Photos1&2.cdr

PWA

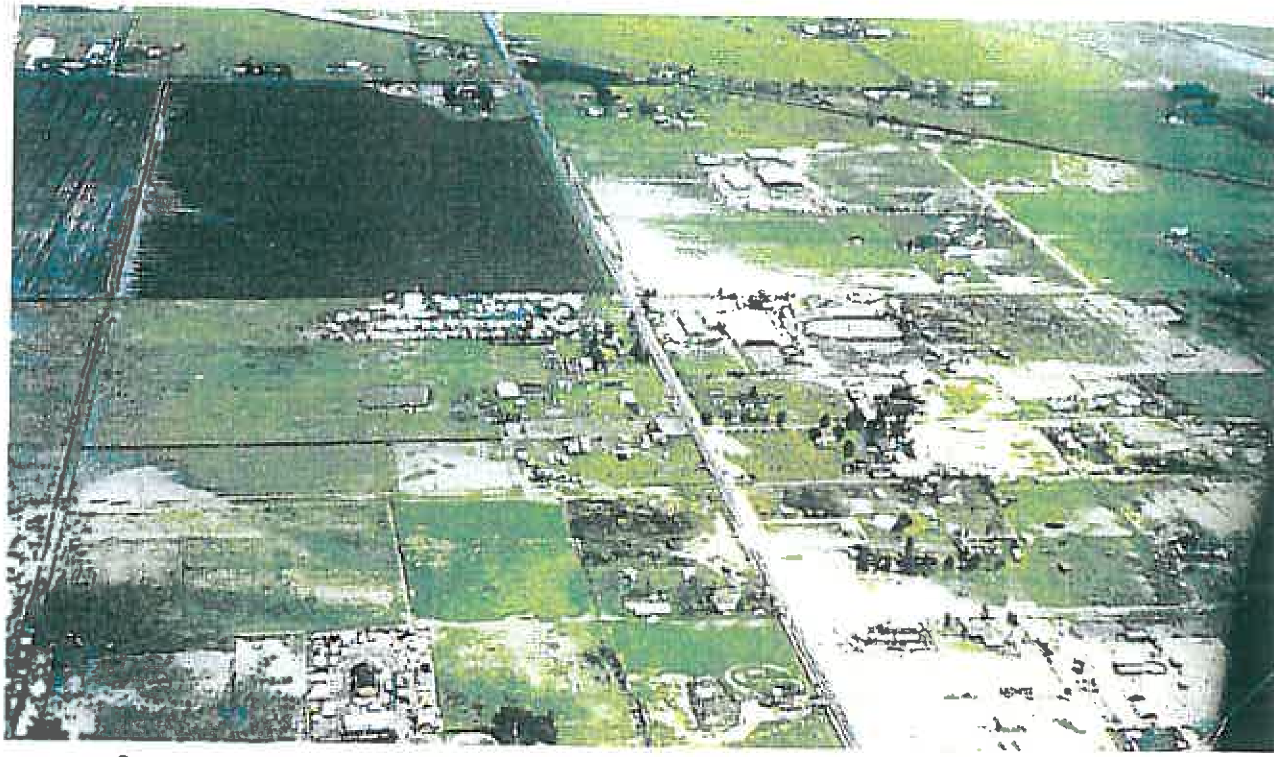


Photo 3

Photo 4

Projects\1565 Photos3&4.cdr

Photo source: Seth Cockrell, Chair, Knightsen Town Advisory Council

PWA

figure 2

Knightsen Project

Piezometer Locations

Project#1565 Piezometer.cdr

PWA

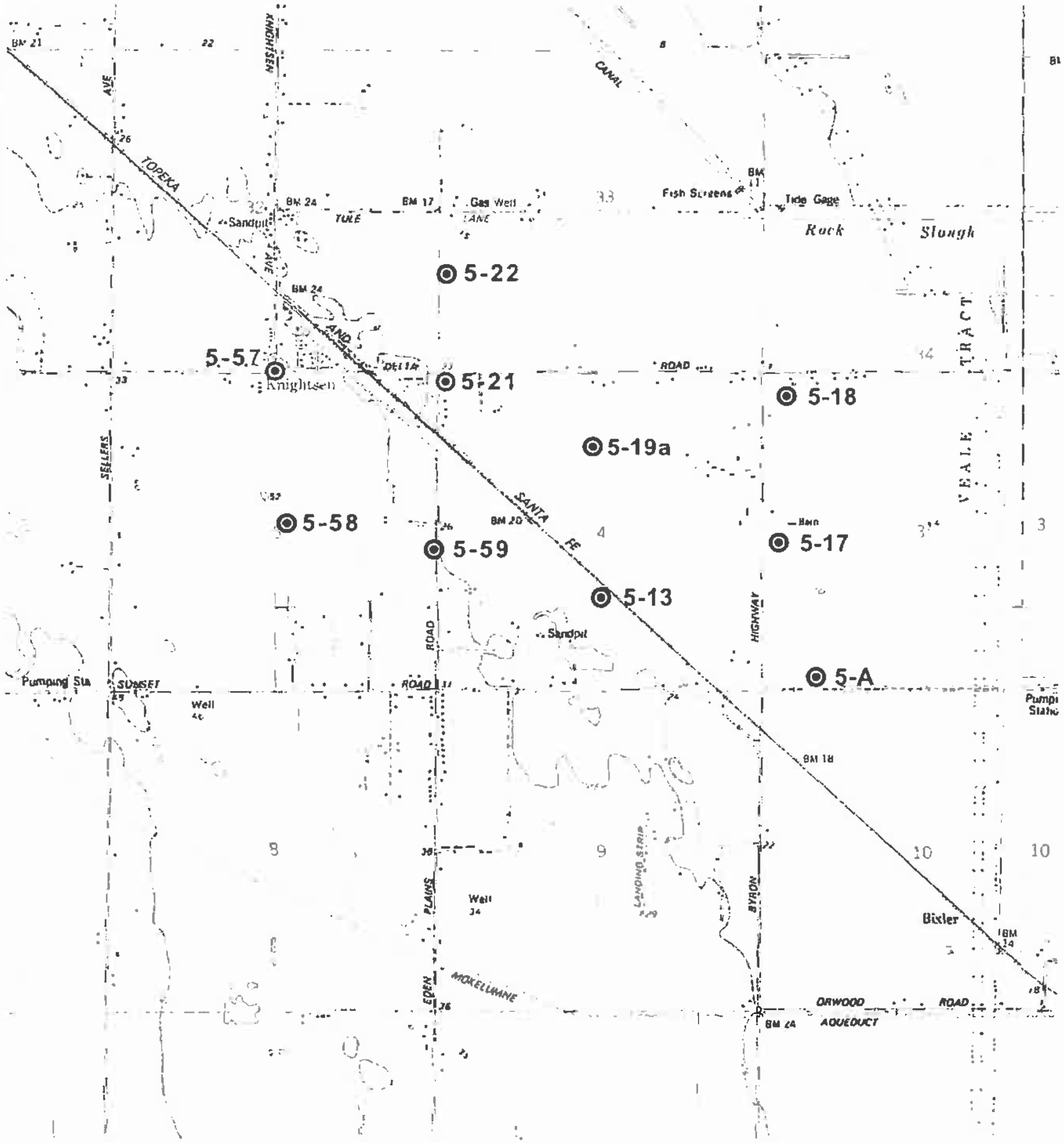


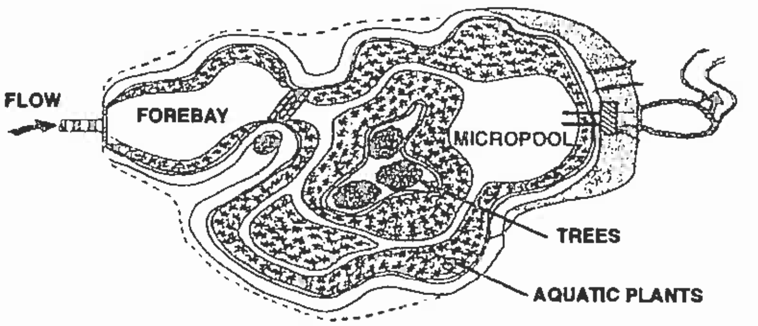
figure 3

Knightsen Project

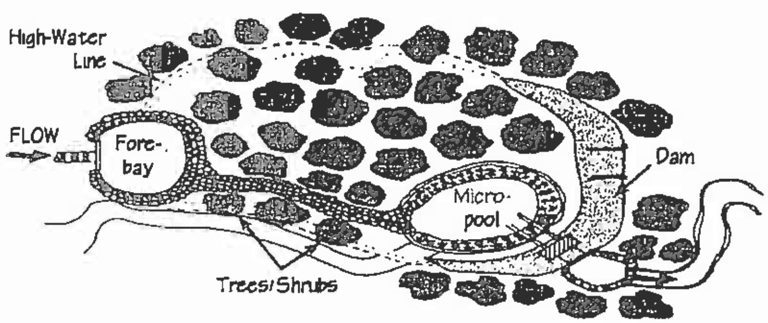
Treatment Control BMP Options

Source: SWQTF, 1993

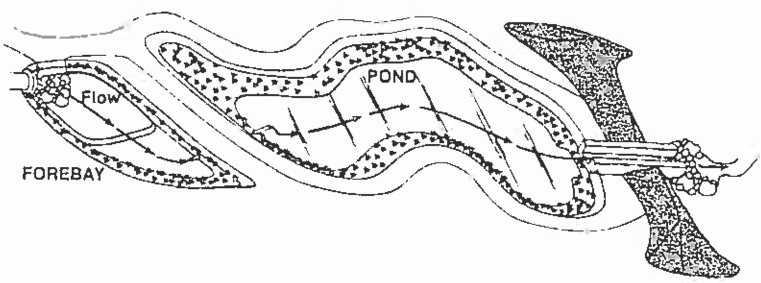
Project#1565 Options.cdr PWA



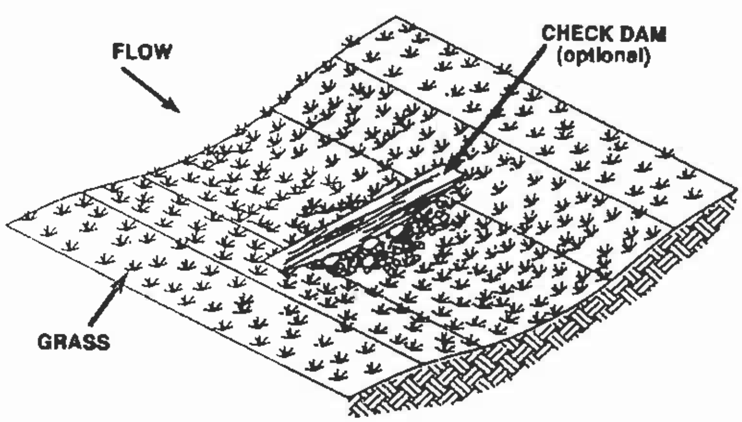
Constructed Treatment Wetland



Extended Detention Basin



Wet Pond



Biofilter Swale

Photo **5** Flooding along Byron highway just south of Delta Road

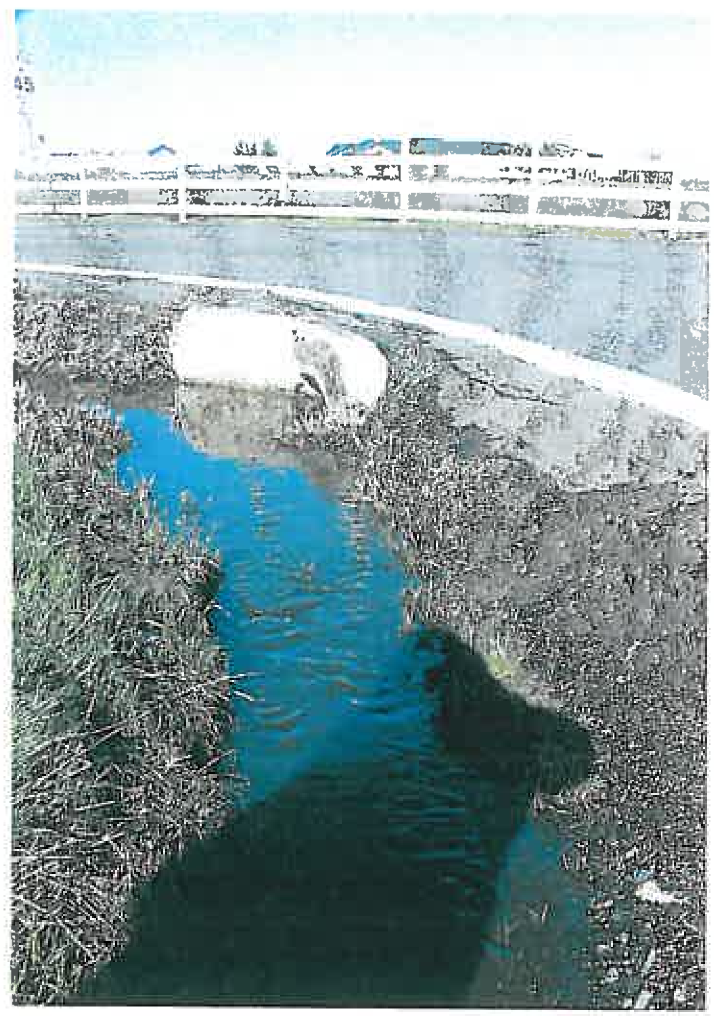


Photo **6** Highpoint in Byron Highway ditch restricting drainage

PWA

Photo 7 Blocked culvert on Delta Road restricting drainage

Photo 8 Flooding along Byron Highway near Iron Horse Road

Photo **9** Ditch on Byron Highway flooded south of Iron Horse Road indicating that a blocked culvert or highpoint in ditch is restricting drainage

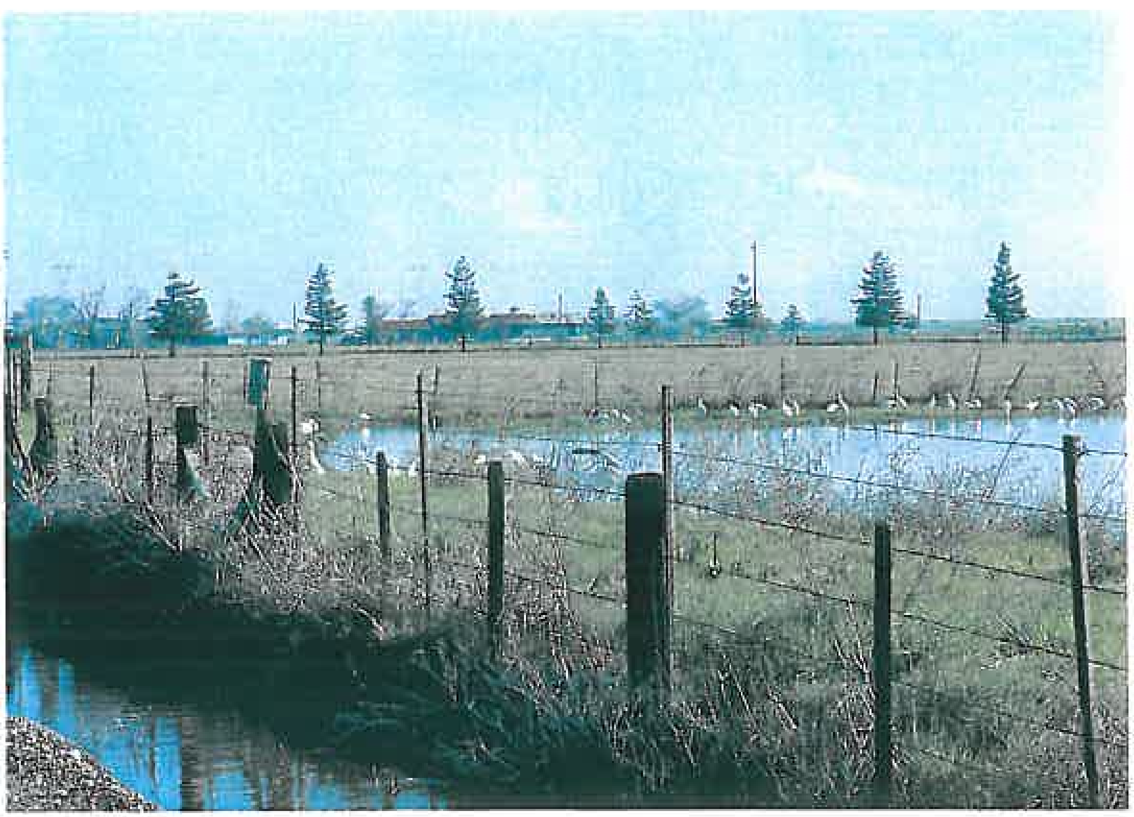


Photo **10** Egrets on potential seasonal wetland habitat

Photo ***11*** Potential seasonal wetland habitat

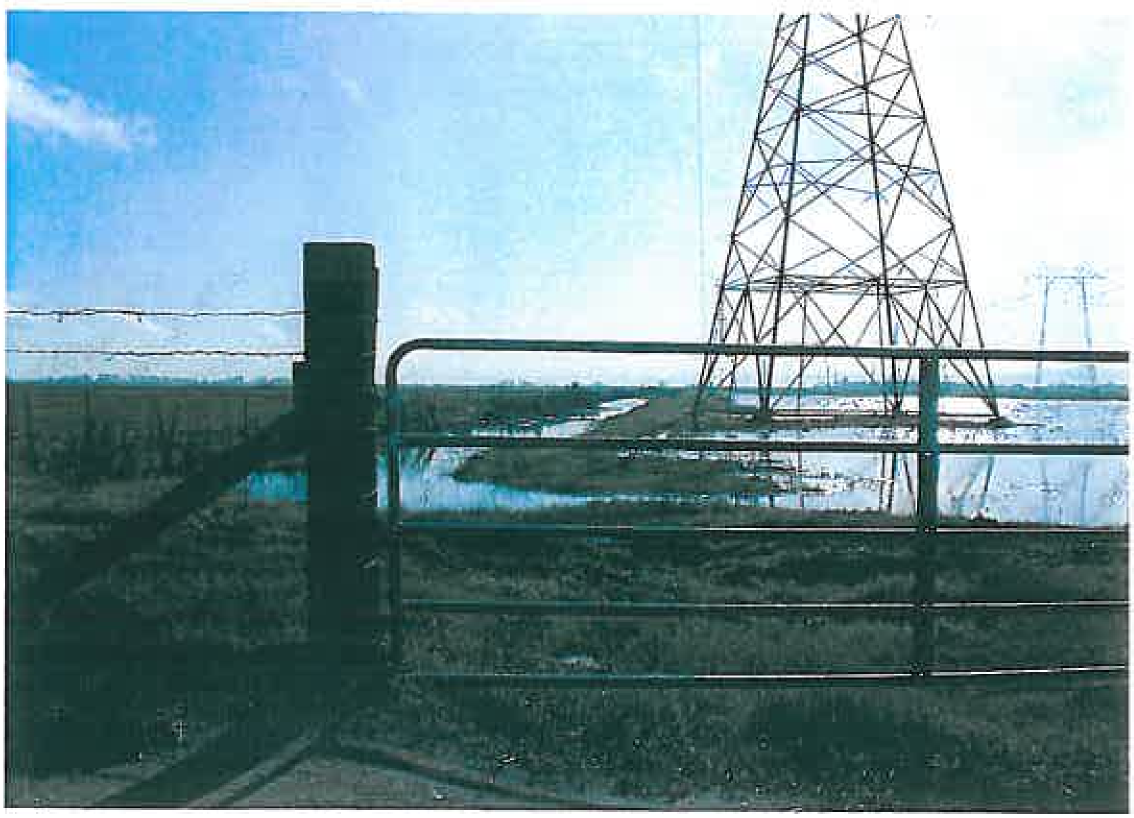


Photo ***12*** Potential seasonal wetland habitat with PG&E channel

APPENDIX A
Peak Discharge Estimation: Rational Method

Peak Discharge Estimation: Rational Method

PWA used the Rational Method to estimate peak discharge at a variety of locations within the larger Knightsen watershed. The Rational Method formulation to calculate peak discharge can be expressed as:

$$Q = C * f * I * A$$

where Q is peak discharge (cfs), C is the run-off coefficient, f is the adjustment factor for a 10-, 25-, 50-, or 100-year event peak discharge, I is the rainfall intensity (in/hr), and A is the sub-watershed area (acres). The value for used for C was 0.45 (CCC Hydrology Manual), which is the coefficient used for pastureland with low infiltration rates (an infiltration rate of 0.09 in/hr has been recorded for this area by Flett & Assoc., 1985). The rainfall intensity was calculated by the equation:

$$I = Pd * (60 / tc)$$

where Pd is the precipitation depth (in), which was determined for each storm event by the depth-duration-frequency curves in the Contra Costa County Hydrology Manual, and tc is the time of concentration (min). For the Rational Method, storm duration is selected by setting it equal to the time of concentration. Time of concentration for each storm event was determined by using the Velocity Method. The Velocity Method formula for determining time of concentration can be expressed as:

$$tc = \Sigma Li / 60\, vi$$

where Li is the flowpath length for each sub-watershed (ft), and vi is the velocity of flow for each sub-watershed (ft/s). The value for vi was calculated by a form of Manning's equation that can be expressed as:

$$vi = k\, s^{1/2}$$

where s is sub-watershed slope (ft/ft) and k can be considered a constant ($k = [1.49\, R^{2/3}]/n$). The value for k used in this analysis was 0.7, which is appropriate for short grass pastureland. Slope values for each sub-watershed were taken from the USGS topographic map of the region.

Knightsen Hydrology: Peak Discharge Estimates

WS#	Watershed Characteristics									100-year			50-year			25-year			10-year		
(see map)	Area (acres)	L (m)	L (ft)	High EL (ft)	Low EL (ft)	S	v (ft/s)	tc (min)	tc (hour)	Pd (in)	I (in/hr)	Q (cfs)	Pd (in)	I (in/hr)	Q (cfs)	Pd (in)	I (in/hr)	Q (cfs)	Pd (in)	I (in/hr)	Q (cfs)
Sub-Watersheds																					
1	396	1750	5741	30	10	0.35%	0.41	232	3.9	1.7	0.44	98	1.5	0.38	80	1.4	0.35	69	1.2	0.30	53
2	950	2150	7054	25	1	0.34%	0.41	288	4.8	1.8	0.36	195	1.6	0.33	171	1.5	0.30	142	1.3	0.26	111
3	321	1950	6398	35	25	0.16%	0.28	385	6.4	2.1	0.33	59	1.9	0.30	51	1.7	0.26	42	1.5	0.23	33
4	684	3600	11811	25	0	0.21%	0.32	611	10.2	2.6	0.25	96	2.3	0.23	83	2.0	0.19	65	1.7	0.17	51
5	1537	4400	14436	65	25	0.28%	0.37	653	10.9	2.6	0.24	207	2.3	0.21	175	2.1	0.19	147	1.8	0.16	111
6	1146	4750	15584	65	20	0.29%	0.38	690	11.5	2.7	0.23	151	2.4	0.21	129	2.2	0.19	106	1.8	0.16	81
7	189	1900	6234	25	7	0.29%	0.38	276	4.6	1.8	0.38	40	1.6	0.34	34	1.5	0.31	29	1.2	0.26	22
8	235	1550	5085	20	7	0.26%	0.35	239	4.0	1.7	0.43	56	1.5	0.36	46	1.4	0.34	39	1.2	0.29	31
9	473	1900	6234	17	0	0.27%	0.37	284	4.7	1.8	0.37	98	1.6	0.33	84	1.5	0.31	72	1.2	0.26	55
10	875	3700	12139	40	0	0.33%	0.40	504	8.4	2.3	0.27	132	2.1	0.25	118	1.9	0.23	98	1.6	0.18	73
Composites																					
1&2	1346	3350	10991	30	1	0.26%	0.36	509	8.5	2.3	0.26	201	2.1	0.25	180	1.9	0.22	149	1.6	0.19	114
3,5,&6	3004	5650	18537	65	20	0.24%	0.34	896	14.9	3.0	0.20	340	2.7	0.18	293	2.4	0.16	239	2.0	0.13	181
3,5,6,&8	3239	7200	23622	65	7	0.25%	0.35	1135	18.9	3.3	0.17	318	3.0	0.16	277	2.6	0.14	220	2.2	0.12	169
3,5,6,7,&8	3428	7200	23622	65	7	0.25%	0.35	1135	18.9	3.3	0.17	336	3.0	0.16	294	2.6	0.14	233	2.2	0.12	179
3,5,6,7,8,&9	3901	8400	27559	65	0	0.24%	0.34	1351	22.5	3.5	0.16	341	3.2	0.14	299	2.8	0.12	236	2.3	0.10	179
7&8	424	1900	6234	25	7	0.29%	0.38	276	4.6	1.8	0.38	91	1.6	0.34	77	1.5	0.31	66	1.2	0.26	50
7,8,&9	897	3100	10171	25	0	0.25%	0.35	488	8.1	2.3	0.28	139	2.1	0.26	125	1.9	0.23	101	1.5	0.18	74

Rational Method: Flow = Q = C * I * f * (Sub-Watershed Area)
C = runoff coefficient
C for flat pastureland with low infiltration = 0.45
I = rainfall intensity = Pd*tc
f_{year} = adjustment factor for various events:

f_{10}	1
f_{25}	1.1
f_{50}	1.2
f_{100}	1.25

Pd = precipitation depth (from depth-duration-frequency curve for CCC)
[mean seansonal rainfall taken as 10.5 in (from Flett & Assoc., 1985)]
tc = time of concentration, using the velocity method:
tc = Σ L/v
L = length of sub-watershed flowpath
v = velocity, v=kS^.5
k for short grass pasture = 0.7
S = sub-watershed slope

APPENDIX B
Runoff Volume Estimation: SCS Curve Number Equation

Runoff Volume Estimation: SCS Curve Number Equation

Surface runoff volumes were estimated for each sub-watershed using the SCS curve number equation developed by the Natural Resource Conservation Service (Haan, 1994):

$$D = (R - 0.2s)^2 / (R + 0.8s)$$

where D is the direct runoff volume (in.) and R is the storm rainfall depth (in). The value for storm depth for the 10-year and 100-year events for each sub-watershed was taken from depth-frequency-duration curves for Contra Costa County for a mean seasonal precipitation of 10.5 inches (Contra Costa County Public Works Department, 1977). The s variable is a retention parameter that can be expressed as:

$$s = (1000/CN) - 10$$

where CN is a runoff curve number which is based on soils and land use in the watershed. A CN value of 74, which is indicative of pastureland with moderate grazing in moderate to poorly drained soil, was used for all of the sub-watersheds in the Knightsen region. In general, the SCS curve number equation is only valid for conditions where $R > 0.2s$.

Knightsen Hydrology:
Runoff Volume Estimates

		SCS Curve Number Approach			
		100 year events		10 year events	
WS# *(see map)*	Area (acres)	12 hr (acre-ft)	24 hr (acre-ft)	12 hr (acre-ft)	24 hr (acre-ft)
1	396	22	39	7.9	16.5
2	950	53	93	19.0	39.5
3	321	18	31	6.4	13.3
4	684	38	67	13.7	28.5
5	1537	85	150	30.8	64.0
6	1146	64	112	23.0	47.7
7	189	10	18	3.8	7.9
8	235	13	23	4.7	9.8
9	473	26	46	9.5	19.7
10	875	49	85	17.5	36.4
Cumulative					
1 & 2	1346	75	131	27	56
7 & 8	424	23	41	8	18
3, 5, & 6	3004	167	293	60	125
+ 7 & 8	3428	190	335	69	143
+ 9	3901	216	381	78	162

SCS Curve Number Approach
NRCS (1972) equation for runoff volume estimate
Direct Runoff = D = $[(R - 0.2\ S)^2] / (R + 0.8\ S)$
S = (1000/CN)-10
CN = runoff curve number
CN = 74
S = 3.51
R = storm rainfall depth
(from frequency-depth-duration curve)

Runoff Depth

	100-yr		10-yr	
	R, in	D, in	R, in	D, in
12-hr	2.6	0.67	1.75	0.24
24-hr	3.4	1.17	2.3	0.50

APPENDIX C
Groundwater Data

Table 3
Knightsen Hydrology: Groundwater Data

Piezometer	Date	Top of Casing (ft NGVD)	Depth to Water (ft)	Groundwater Elevation (ft NGVD)	Location / Comment
5-A	8/1/00	14.92	7.83	7.09	Eagle Lane east of Byron Highway
	2/8/01		7.58	7.34	
	10/9/01		7.96	6.96	
	12/19/01		DRY	>7.07	DRY (7.85' deep)
	1/11/02		7.41	7.51	
			7.70	7.23	Average
			7.90	7.03	Dry Season Average
			7.50	7.43	Wet Season Average
			7.41	7.51	Minimum DTW
			7.96	6.96	Maximum DTW
5-14	3/18/93	NA	3.00	NA	Northwest of intersection of Byron Highway and Eagle Lane
	10/25/93		5.00	NA	
	10/24/94		5.17	NA	
	3/28/95		2.08	NA	
	10/10/95		3.42	NA	
	11/20/96		4.25	NA	
	11/4/97		3.75	NA	
	2/26/98		0.00	NA	
	4/6/98		0.05	NA	
	7/15/98		3.25	NA	
	4/15/99		3.67	NA	
	9/2/99		3.42	NA	
	3/6/00		3.00	NA	
	8/3/00		3.17	NA	
	3/8/01		3.08	NA	
	10/9/01		3.67	NA	
	12/19/01		DRY	NA	DRY (3.5' deep)
			3.12	NA	Average
			3.90	NA	Dry Season Average
			2.13	NA	Wet Season Average
			0.00	NA	Minimum DTW
			5.17	NA	Maximum DTW

Table 3
Knightsen Hydrology: Groundwater Data

Piezometer	Date	Top of Casing (ft NGVD)	Depth to Water (ft)	Groundwater Elevation (ft NGVD)	Location / Comment
5-17	10/25/93	10.33	6.42	3.91	Byron Highway at Ironhorse Road
	10/24/94		6.17	4.16	
	3/28/95		3.25	7.08	
	10/10/95		5.25	5.08	
	11/20/96		7.67	2.66	
	11/4/97		7.25	3.08	
	2/26/98		0.42	9.91	
	4/6/98		3.42	6.91	
	7/15/98		6.75	3.58	
	4/15/99		6.58	3.75	
	9/2/99		5.33	5.00	
	3/6/00		5.17	5.16	
	8/3/00		6.67	3.66	
	3/9/01		5.58	4.75	
	10/11/01		6.83	3.50	
	12/19/01		5.00	5.33	
	1/11/02		1.45	8.88	
			5.25	5.08	Average
			6.48	3.85	Dry Season Average
			3.86	6.47	Wet Season Average
			0.42	9.91	Minimum DTW
			7.67	2.66	Maximum DTW

Table 3
Knightsen Hydrology: Groundwater Data

Piezometer	Date	Top of Casing (ft NGVD)	Depth to Water (ft)	Groundwater Elevation (ft NGVD)	Location / Comment
5-18	4/17/84	5.69	3.33	2.36	Byron Highway south of Delta Road
	10/5/84		6.00	-0.31	
	11/18/92		5.00	0.69	
	3/18/93		0.50	5.19	
	10/25/93		5.00	0.69	
	10/24/94		4.42	1.27	
	2/28/95		0.04	5.65	
	10/10/95		2.75	2.94	
	11/20/96		3.25	2.44	
	11/4/97		1.75	3.94	
	2/26/98		above grd.	>5.69	PZ flooded (assumed 0.5 feet deep)
	4/6/98		0.04	5.65	
	7/15/98		0.33	5.36	
	4/15/99		0.83	4.86	
	9/2/99		1.25	4.44	
	3/6/00		0.08	5.61	
	8/3/00		1.00	4.69	
	3/8/01		0.50	5.19	
	10/11/01		3.00	2.69	
	12/19/01		2.20	3.49	
	1/11/02		0.08	5.61	
			2.07	3.62	Average
			3.41	2.28	Dry Season Average
			0.42	5.27	Wet Season Average
			above grd.	>5.69	Minimum DTW
			6.00	-0.31	Maximum DTW

Table 3
Knightsen Hydrology: Groundwater Data

Piezometer	Date	Top of Casing (ft NGVD)	Depth to Water (ft)	Groundwater Elevation (ft NGVD)	Location / Comment
5-21	4/17/84	20.73	8.00	12.73	Delta Road east of Eden Plains Road
	10/3/84		10.00	10.73	
	11/18/92		9.42	11.31	
	3/18/93		6.00	14.73	
	10/26/93		9.00	11.73	
	10/24/94		8.42	12.31	
	3/28/95		7.58	13.15	
	10/10/95		8.42	12.31	
	11/20/96		8.25	12.48	
	11/4/97		8.75	11.98	
	2/26/98		2.50	18.23	
	4/6/98		4.75	15.98	
	7/15/98		6.75	13.98	
	4/15/99		8.25	12.48	
	9/2/99		8.42	12.31	
	3/6/00		7.50	13.23	
	8/3/00		6.50	14.23	
	3/8/01		8.17	12.56	
	10/11/01		10.33	10.40	
	12/19/01		8.87	11.86	
	1/11/02		9.75	10.98	
			7.89	12.84	Average
			8.57	12.16	Dry Season Average
			7.14	13.59	Wet Season Average
			2.50	18.23	Minimum DTW
			10.33	10.40	Maximum DTW

Table 3
Knightsen Hydrology: Groundwater Data

Piezometer	Date	Top of Casing (ft NGVD)	Depth to Water (ft)	Groundwater Elevation (ft NGVD)	Location / Comment
5-22	4/17/84	NA	2.50	NA	Bartles Road between Tule Lane and Delta Road
	10/3/84		7.42	NA	
	11/18/92		8.00	NA	
	3/18/93		9.00	NA	
	10/25/93		7.17	NA	
	10/24/94		7.00	NA	
	3/28/95		3.17	NA	
	10/10/95		6.50	NA	
	11/20/96		6.50	NA	
	11/4/97		6.25	NA	
	2/26/98		0.42	NA	
	4/6/98		1.92	NA	
	7/15/98		2.17	NA	
	4/18/99		5.92	NA	
	9/9/99		5.75	NA	
	3/6/00		4.58	NA	
	8/3/00		3.58	NA	
	3/8/01		6.17	NA	
	10/11/01		8.79	NA	
	12/19/01		7.30	NA	
			5.51	NA	Average
			6.28	NA	Dry Season Average
			4.21	NA	Wet Season Average
			0.42	NA	Minimum DTW
			9.00	NA	Maximum DTW

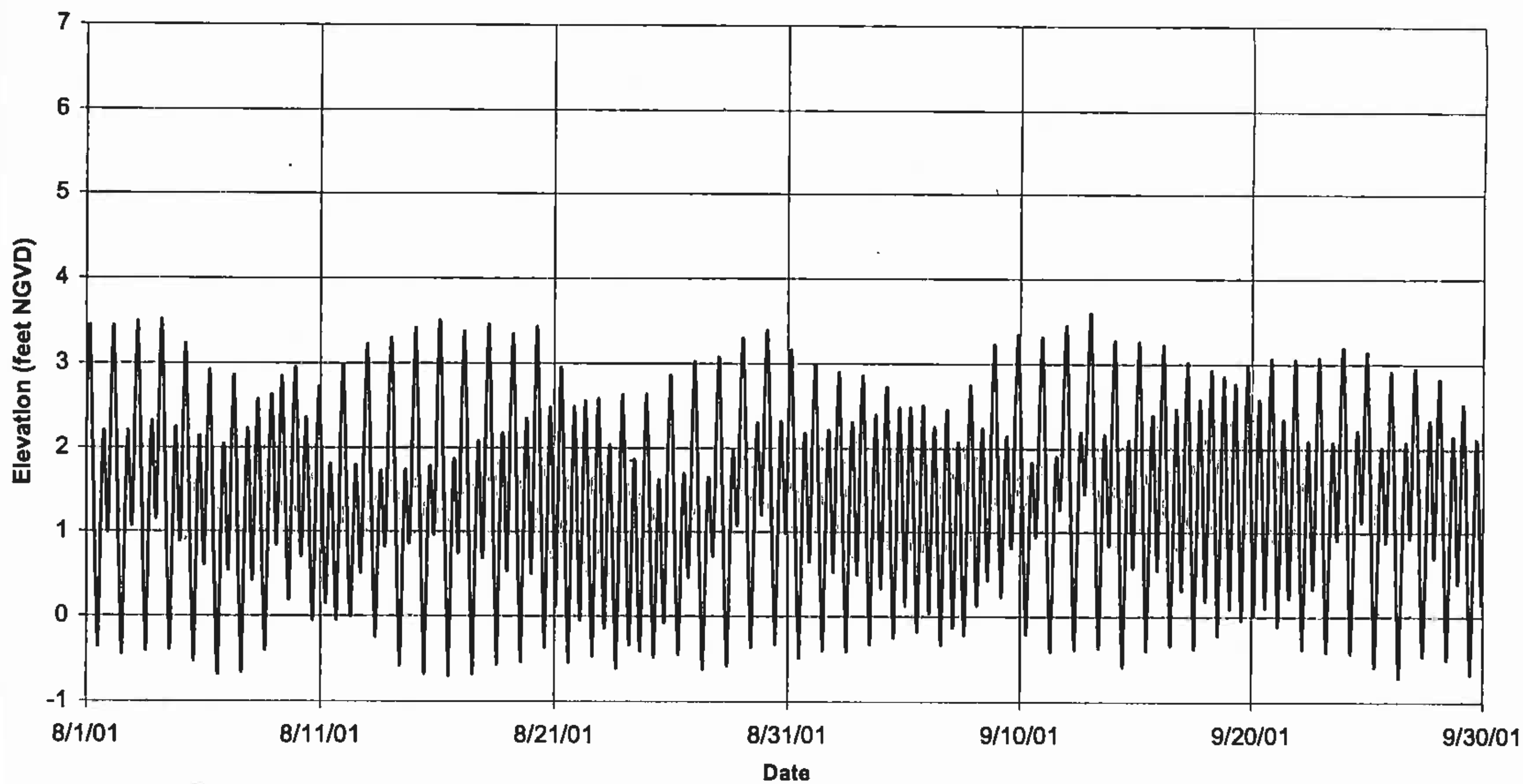
Table 3
Knightsen Hydrology: Groundwater Data

Piezometer	Date	Top of Casing (ft NGVD)	Depth to Water (ft)	Groundwater Elevation (ft NGVD)	Location / Comment
5-57	4/23/84	22.28	1.42	20.86	Delta Road at Curlew Connex Road
	10/2/84		4.00	18.28	
	11/20/92		4.42	17.86	
	3/25/93		1.00	21.28	
	10/26/93		4.67	17.61	
	10/25/94		4.00	18.28	
	3/29/95		1.08	21.20	
	10/11/95		4.08	18.20	
	12/2/96		4.08	18.20	
	2/26/98		above grd.	>22.98	PZ flooded (assumed 0.5 feet deep)
	4/6/98		above grd.	>22.98	PZ flooded (assumed 0.1 feet deep)
	7/15/98		1.00	21.28	
	4/21/99		3.58	18.70	
	9/13/99		4.00	18.28	
	3/6/00		0.75	21.53	
	8/9/00		4.00	18.28	
	3/9/01		3.67	18.61	
	10/26/01		5.25	17.03	
	12/19/01		5.05	17.23	
	1/11/02		4.78	17.50	
			3.38	18.90	Average
			3.94	18.34	Dry Season Average
			2.07	20.21	Wet Season Average
			above grd.	>22.98	Minimum DTW
			5.25	17.03	Maximum DTW

Table 3
Knightsen Hydrology: Groundwater Data

Piezometer	Date	Top of Casing (ft NGVD)	Depth to Water (ft)	Groundwater Elevation (ft NGVD)	Location / Comment
5-59	4/23/84	NA	6.00	NA	Eden Plains road between
	10/2/84		7.42	NA	Sunset Road and Delta Road
	11/20/92		8.42	NA	
	3/25/93		5.00	NA	
	10/26/93		8.42	NA	
	10/25/94		8.00	NA	
	3/29/95		5.25	NA	
	10/11/95		7.75	NA	
	12/2/96		7.83	NA	
	2/26/98		1.00	NA	
	4/6/98		3.50	NA	
	7/15/98		6.67	NA	
	4/21/99		7.17	NA	
	9/13/99		7.08	NA	
	3/1/00		6.17	NA	
	8/9/00		6.75	NA	
	3/9/01		7.00	NA	
	10/26/01		9.88	NA	
	12/19/01		9.42	NA	
			6.78	NA	Average
			7.82	NA	Dry Season Average
			5.44	NA	Wet Season Average
			1.00	NA	Minimum DTW
			9.88	NA	Maximum DTW

APPENDIX D
Tide Elevation Plots



Rock Slough Tide - August and September 2001

Figure 3: Knightsen Hydrology: Tide Elevations

Rock Slough Tide Elevation Measurements
August and September 2001

PWA

PWA#: 1565

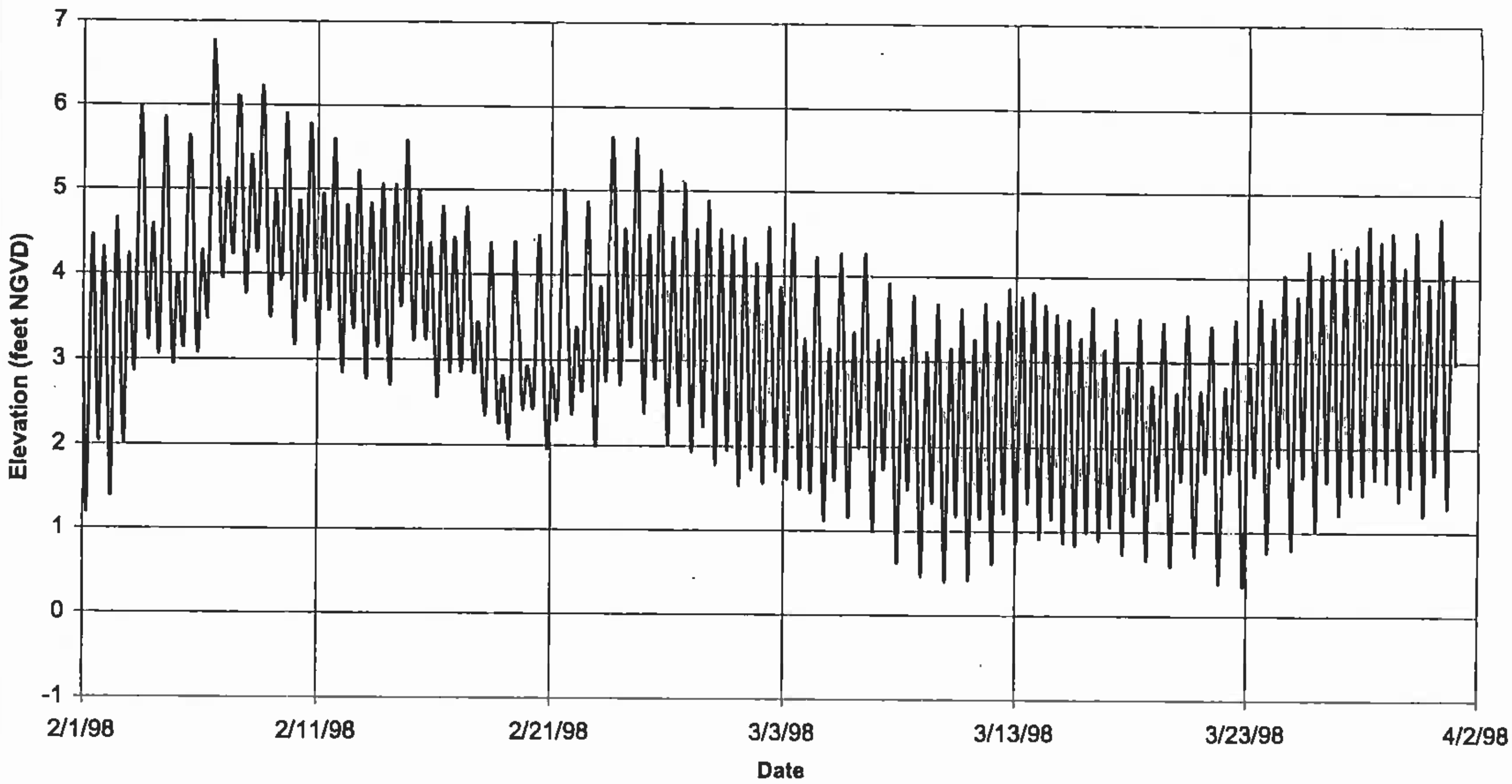


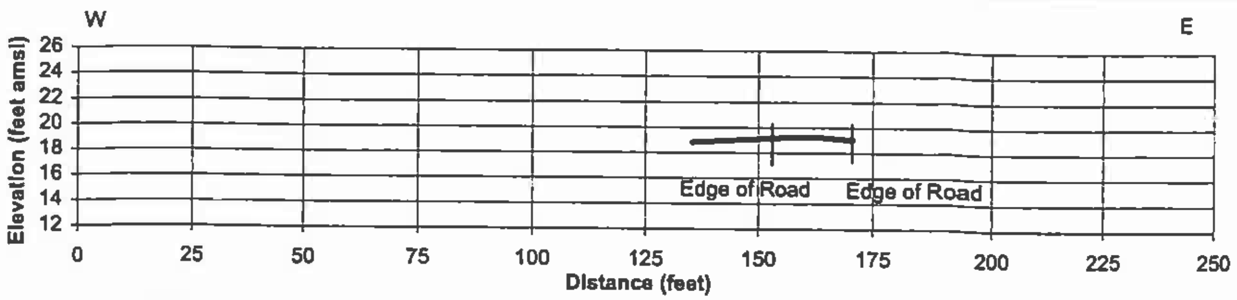
Figure 4: Knightsen Hydrology: Tide Elevations

Rock Slough Tide Elevation Measurements
February and March 1998

PWA | PWA#: 1565

APPENDIX E
Survey Cross-Sections

BYRON HIGHWAY CROSS SECTIONS

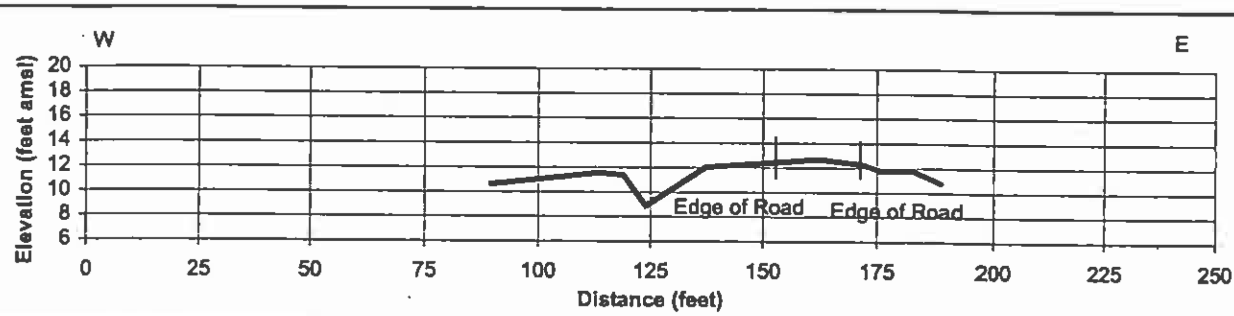


Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 15

Located on Byron Highway, north of Sunset Road

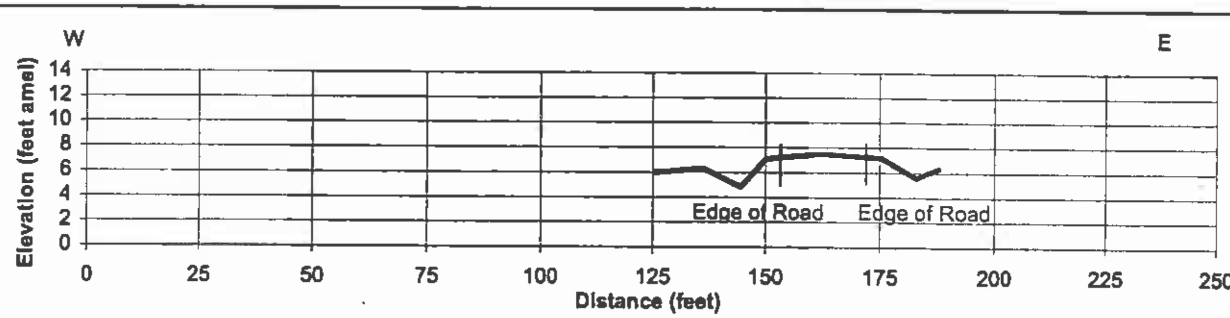
PWA | PWA#: 1565



Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 14; Located on Byron Highway, midway between Delta Road and Sunset Road

PWA | PWA#: 1565



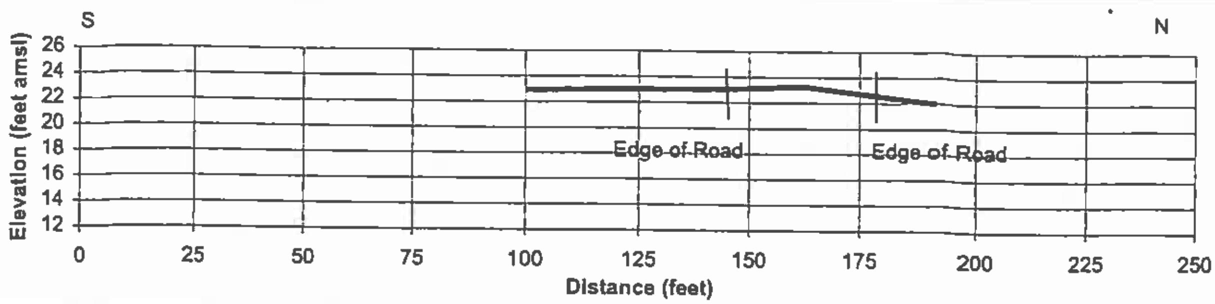
Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 13

Located on Byron Highway, South of Delta Road

PWA | PWA#: 1565

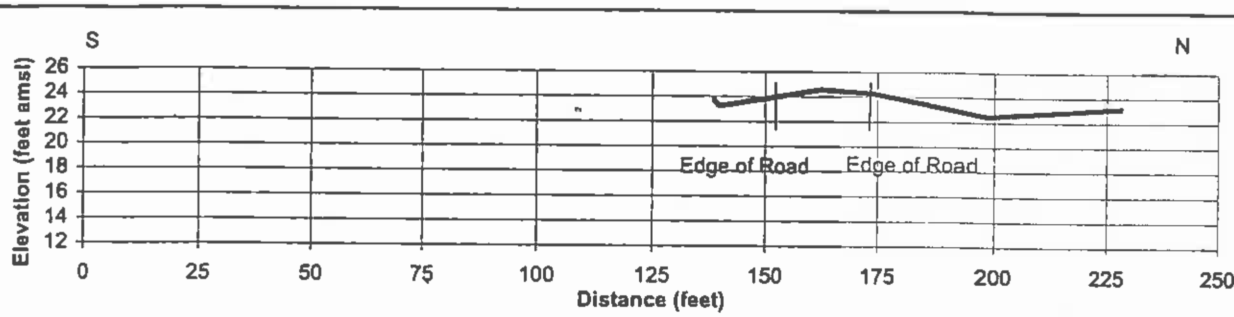
DELTA ROAD CROSS SECTIONS WEST OF EDEN PLAINS ROAD



Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 5
Located on Delta Road, West of Knightsen Avenue

PWA | PWA#: 1565

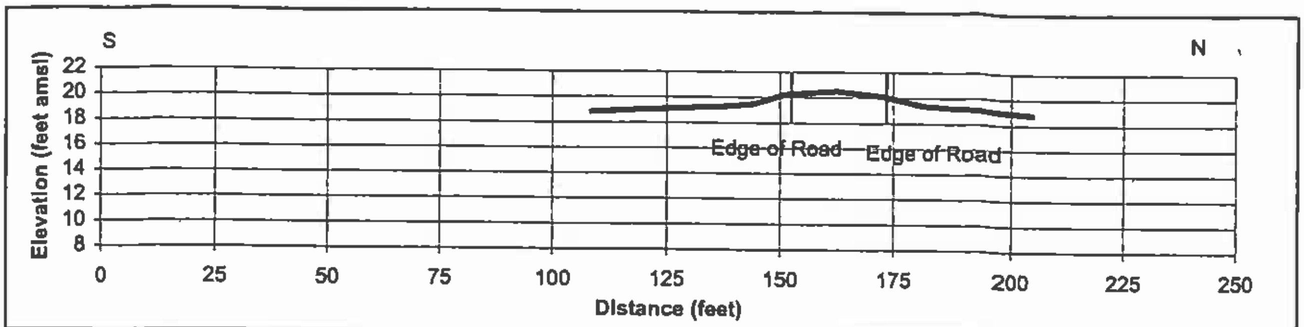


Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 4
Located on Delta Road, West of Eden Plains Road

PWA | PWA#: 1565

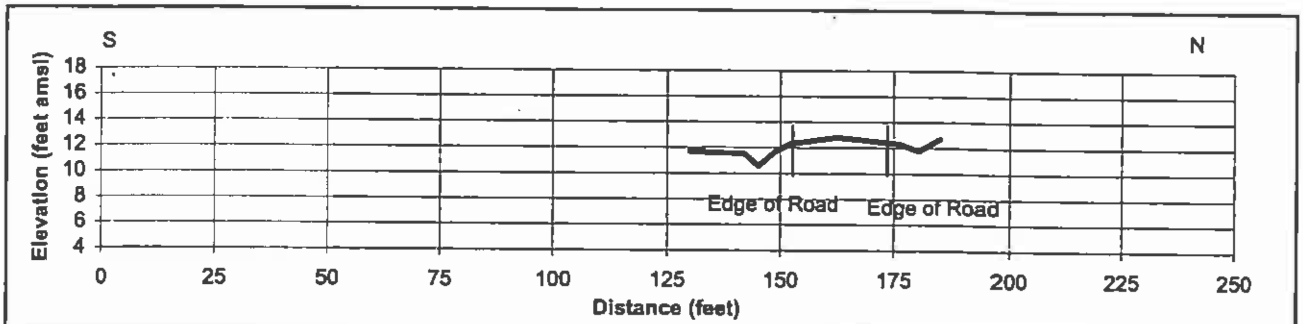
DELTA ROAD CROSS SECTIONS BETWEEN EDEN PLAINS ROAD AND BYRON HIGHWAY



Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 3
Located on Delta Road, East of Eden Plains Road

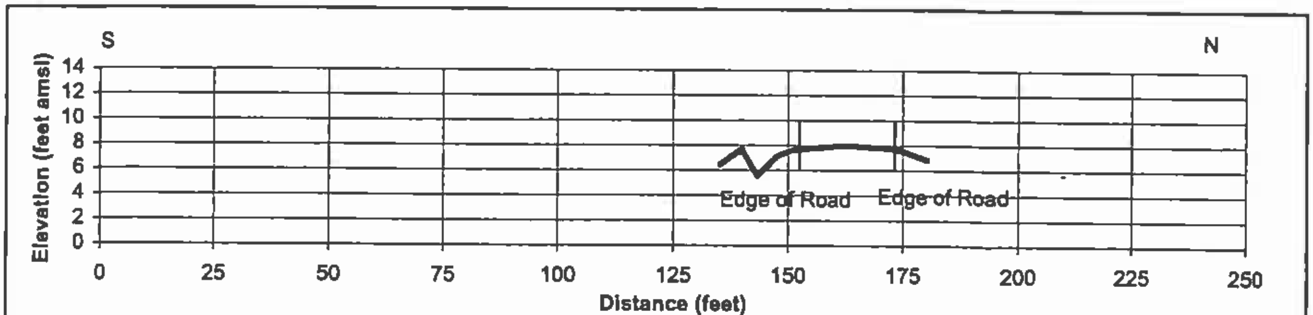
PWA | PWA#: 1565



Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 2; Located on Delta Road,
midway between Eden Plains Road and Byron Highway

PWA | PWA#: 1565

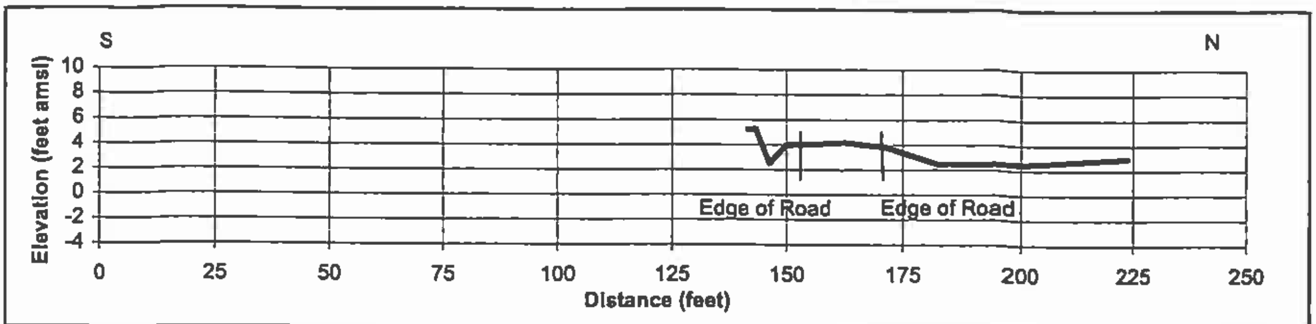


Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 1
Located on Delta Road, West of Byron Highway

PWA | PWA#: 1565

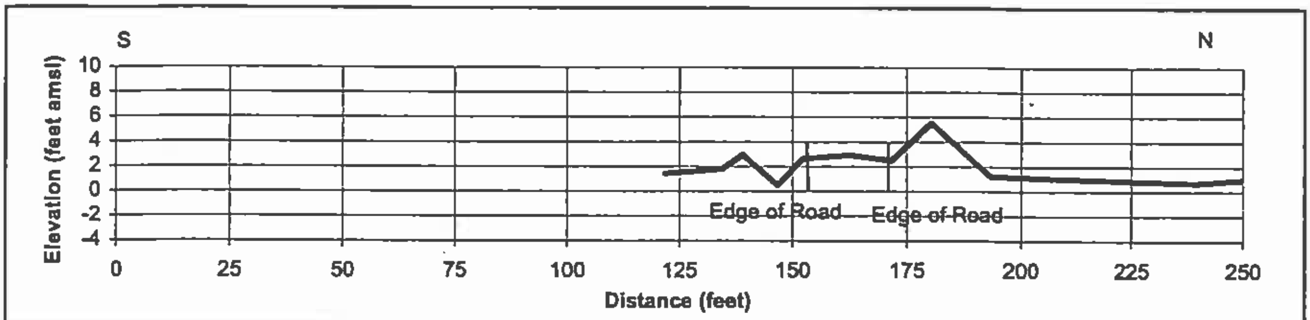
DELTA ROAD CROSS SECTIONS BETWEEN BYRON HIGHWAY AND P.G. & E. EASEMENT



Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 8
Located on Delta Road, East of Byron Highway

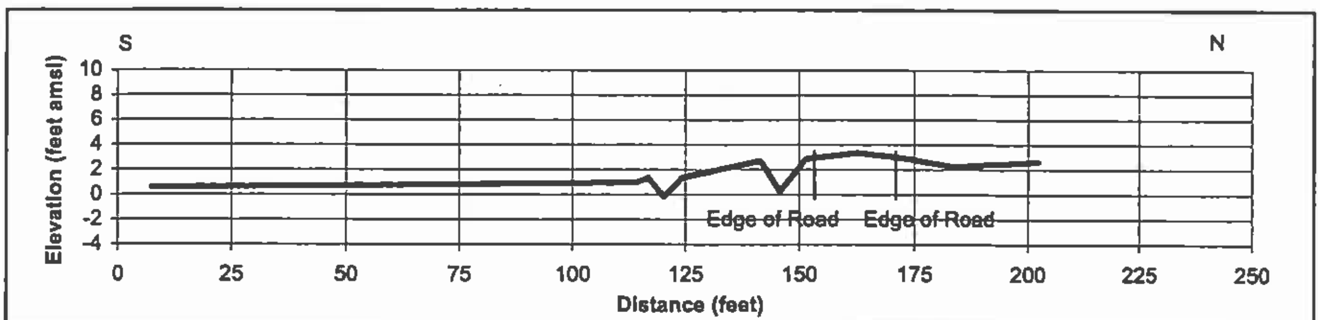
PWA | PWA#: 1565



Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 7; Located on Delta Road,
between Power Towers and Byron Highway

PWA | PWA#: 1565

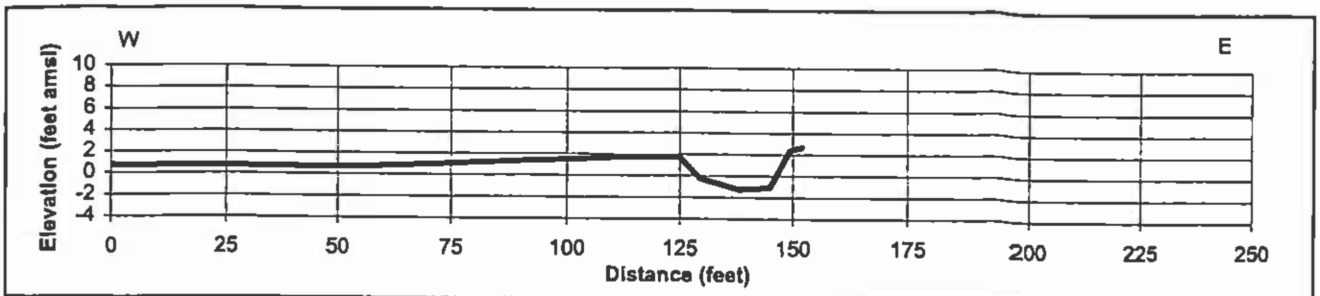


Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 6
Located on Delta Road, West of Power Towers

PWA | PWA#: 1565

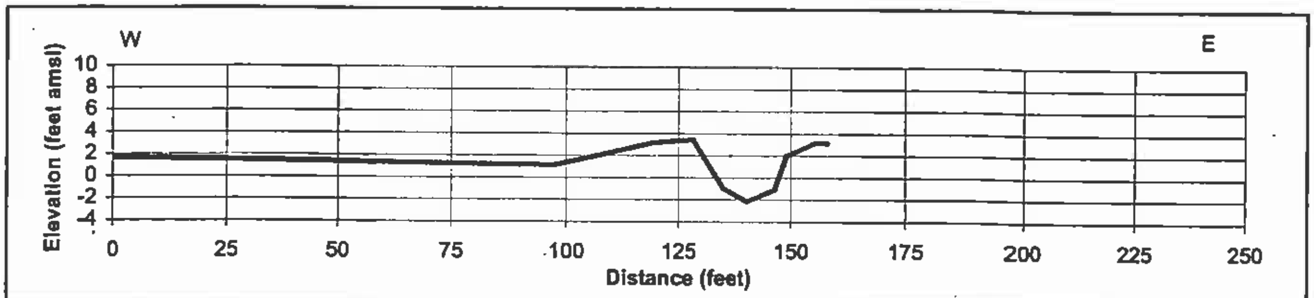
P.G. & E. EASEMENT CROSS SECTIONS



Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 9; Located on Power Tower Drainage Ditch, South of Delta Road

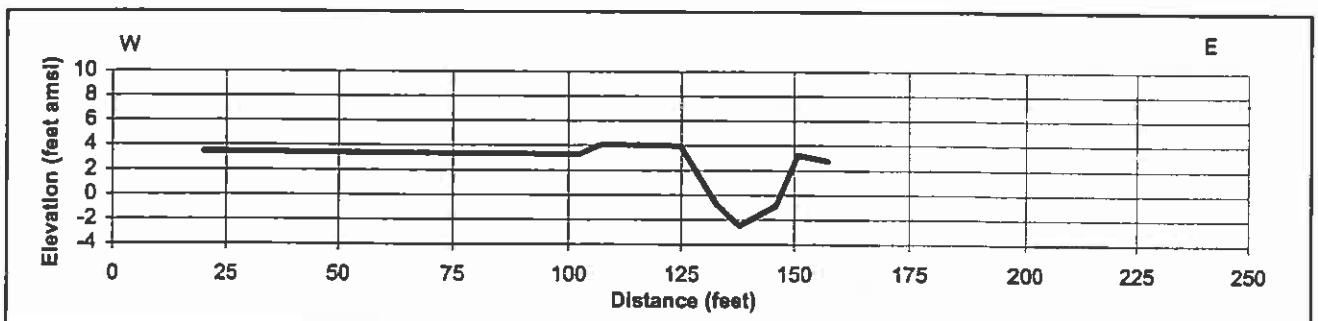
PWA | PWA#: 1565



Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 10; Located on Power Tower Drainage Ditch, South of Cross Section 9

PWA | PWA#: 1565

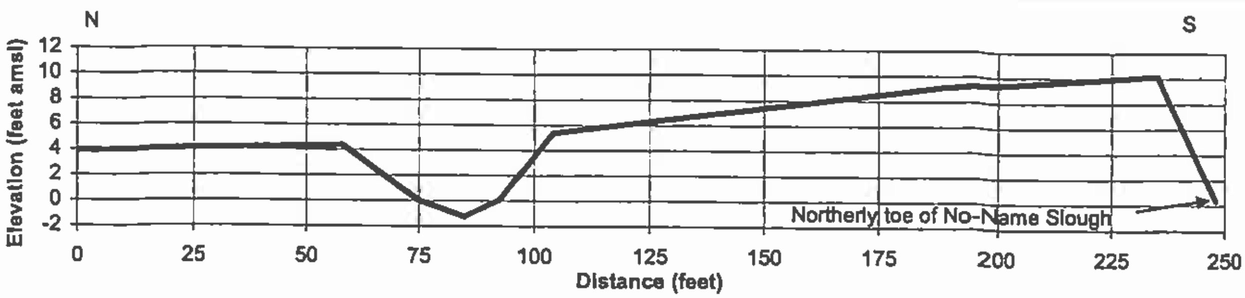


Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 11; Located on Power Tower Drainage Ditch, North of No-Name Slough

PWA | PWA#: 1565

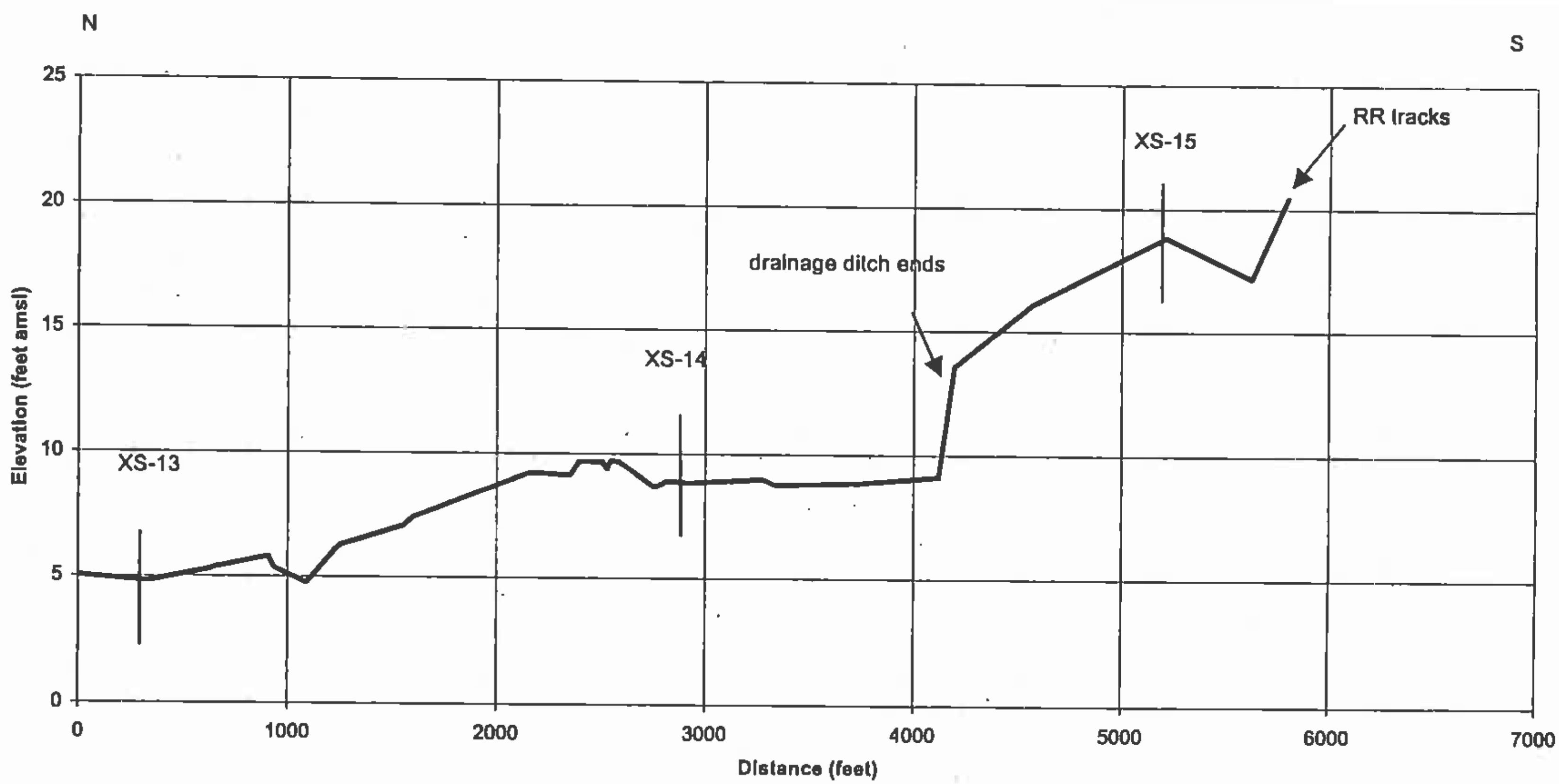
P.G. & E. EASEMENT CROSS SECTIONS



Knightsen Topography: Drainage Ditch Cross Sections

Cross-Section 12; Located on Power Tower Drainage Ditch, West of Junction with No-Name Slough

PWA	PWA#: 1565

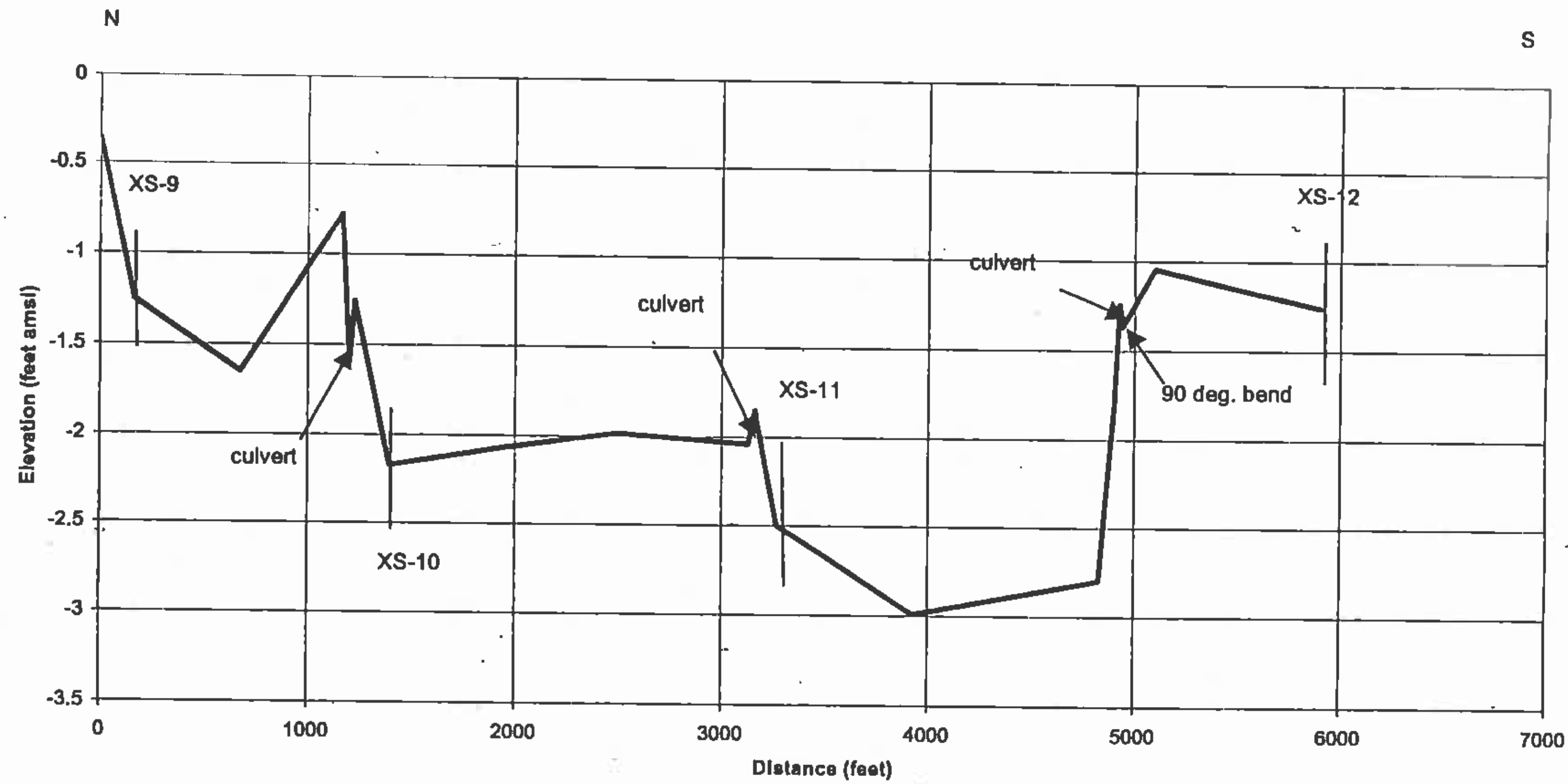


Knightsen Groundwater

Drainage Ditch Profile
West Side of Byron Hwy.
with Cross-Section Locations

PWA

PWA#: 1565

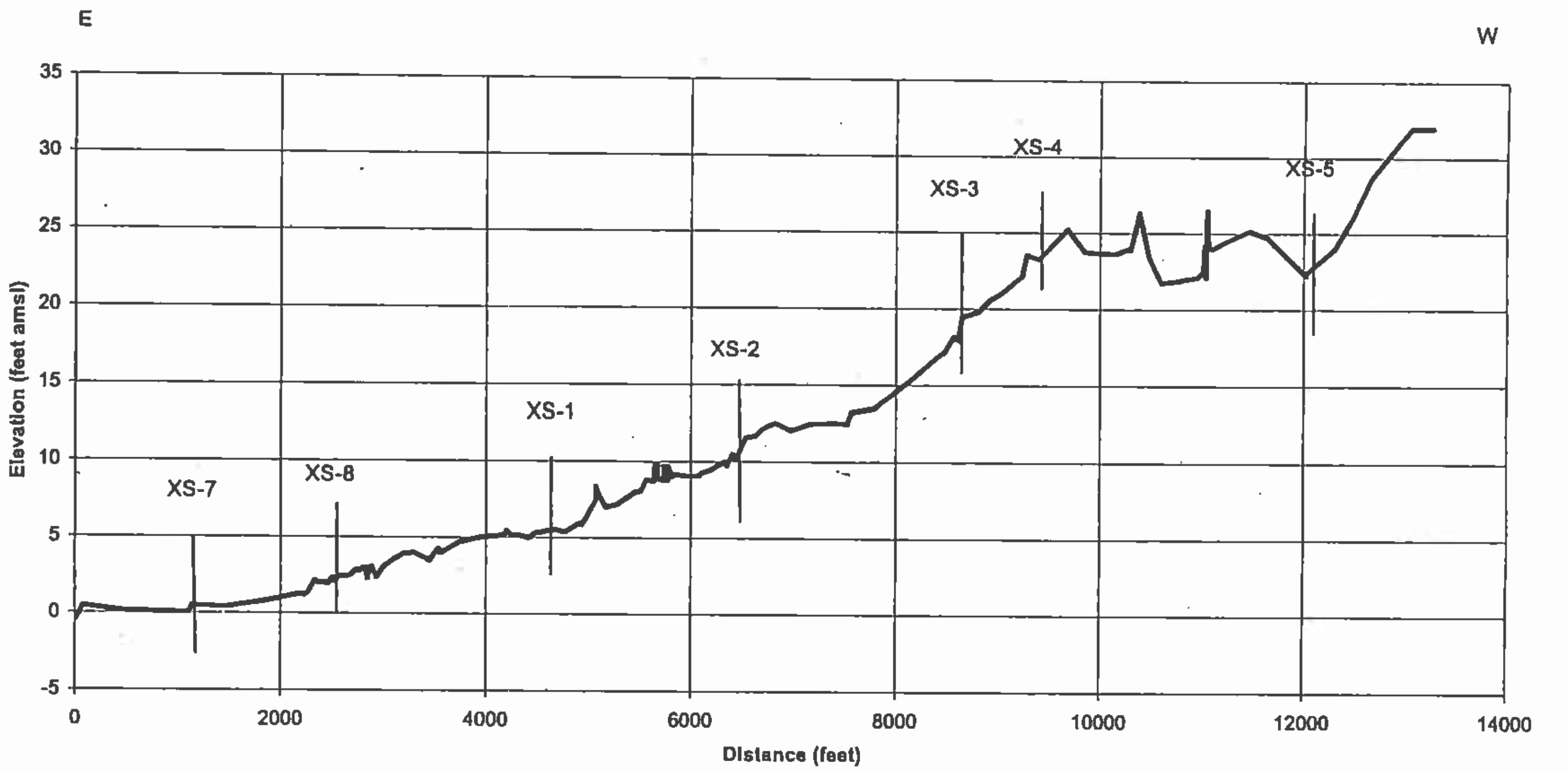


Knightsen Groundwater

Drainage Ditch Profile along Power Tower Lines with Cross-Section Locations

PWA

PWA#: 1565



Knightsen Groundwater

Drainage Ditch Profile
South Side of Delta Road
with Cross-Section Locations

PWA

PWA#: 1565

APPENDIX F
Ditch and Culvert Capacity

Knightsen Topography: Drainage Ditch and Culvert Capacity Estimates

Label (see map)	Location	distance (m)	Source	Description	Diameter (in)	Exposed* (in)	Length (ft)	Width (ft)	Depth (ft)	Area (ft^2)	Wetted Perim. (ft)	Hyd.Rad. (A/P)	Slope	n	Q* (cfs)	10-year Peak Q (cfs)	10-year Peak Q (cfs)
	Delta Road Ditch:															wo/ Bypass	w/ Bypass
XS#5		3700	PWA survey	no ditch													
XS#4		2865	PWA survey	Triangle				12.5	0.5	3.1	12.5	0.2	0.35%	0.035	3.1	2	2
XS#3		2634	PWA survey	no ditch												4	4
	Ohmstede Road	2617	PWA survey	culvert	12	7	50.1			0.8	3.1	0.3	0.35%	0.020	1.4	5	5
	2500 Delta Road	2080	PWA survey	culvert	20	12	30.3			2.2	5.2	0.4	0.35%	0.020	5.3	11	11
		2035	PWA survey	culvert	24	15	24.1			3.1	6.3	0.5	0.35%	0.020	8.7	12	12
XS#2		1972	PWA survey	Triangle				11.2	1.5	8.4	11.6	0.7	0.35%	0.035	17.1	13	13
		1952	PWA survey	culvert	12	0				0.8	3.1	0.3	0.35%	0.020	1.4	13	13
		1777	PWA survey	culvert	19	13	22.0			2.0	5.0	0.4	0.35%	0.020	4.7	15	15
XS#1		1429	PWA survey	Triangle				10.8	2.3	12.4	11.8	1.1	0.35%	0.035	32.3	19	19
C#2	at Byron Highway	1208	PWA survey	cmp	30	13				4.9	7.9	0.6	0.14%	0.025	7.9	179	50
	3091 Delta Road	1081	PWA survey	culvert	18	12	25.0			1.8	4.7	0.4	0.14%	0.020	2.5	179	51
		876	PWA survey	culvert	10	10	18.7			0.5	2.6	0.2	0.14%	0.020	0.5	179	53
	Mercer Avenue	806	PWA survey	culvert	15	12				1.2	3.9	0.3	0.14%	0.020	1.6	179	54
XS#8		787	PWA survey	Triangle				5.9	1.6	4.8	6.8	0.7	0.14%	0.035	6.1	179	54
	3319 Delta Road	730	PWA survey	concrete	18	8				1.8	4.7	0.4	0.14%	0.015	3.4	179	55
XS#7		381	PWA survey	Triangle				15.1	2.6	19.6	16.0	1.2	0.14%	0.035	35.4	179	58
		340	PWA survey	culvert	32	26	23.0			5.6	8.4	0.7	0.14%	0.020	11.8	179	59
XS#6		36	PWA survey	Triangle				9.8	2.4	11.8	10.9	1.1	0.14%	0.035	19.5	179	62
	Byron Highway Ditch:																
XS#15		1396	PWA survey	no ditch									0.50%			4	4
	8560 Byron	810	PWA survey	culvert	18	12	56.0			1.8	4.7	0.4	0.02%	0.020	0.8		15
XS#14		696	PWA survey	Triangle				16.4	2.5	20.7	17.2	1.2	0.02%	0.035	12.4	169	18
	8476 Byron	575	PWA survey	culvert	10	10	22.2			0.5	2.6	0.2	0.18%	0.020	0.6	169	20
	8160 Byron	275	PWA survey	culvert	18	4	30.3			1.8	4.7	0.4	0.18%	0.020	2.9	169	26
XS#13		101	PWA survey	Triangle				12.1	1.5	9.0	12.5	0.7	0.18%	0.035	12.9	169	29
	Power Tower Ditch:																
XS#9		50	PWA survey	Parabolic				24.4	3.0	49.2	25.4	1.9	0.01%	0.035	38.3	179	62
C#9		370	PWA survey	pipe	60	42	24.4			19.6	15.7	1.3	0.01%	0.020	20.0	179	64
XS#10		425	PWA survey	Parabolic				24.9	5.4	89.4	28.0	3.2	0.01%	0.035	97.1	179	65
C#10		959	PWA survey	pipe	60	49	32.4			19.6	15.7	1.3	0.01%	0.020	20.0	179	68
XS#11		996	PWA survey	Parabolic				24.0	5.7	91.1	27.6	3.3	0.01%	0.035	101.3	179	69
C#11		1497	PWA survey	pipe	60	48	24.5			19.6	15.7	1.3	0.01%	0.020	20.0	179	72
XS#12		1799	PWA survey	Parabolic				45.9	5.9	180.8	48.0	3.8	0.01%	0.035	219.5	179	74
	Others:																
C#1	Delta Rd, west of RR tracks	3244	PWA & M&A, 1998	pipe	24	0				3.1	6.3	0.5	0.01%	0.025	1.2	33	
C#3	Eden Plains Rd S of RR tracks		M&A, 1998	cmp	18					1.8	4.7	0.4	0.33%	0.025	3.2	111	
C#4	RR tracks N of Sunset Rd & W of Byron Hwy		M&A, 1998	box				2.5	3.2	7.9	11.3	0.7	0.33%	0.015	35.6	181	
C#4	RR tracks N of Sunset Rd & W of Byron Hwy		M&A, 1998	cmp	24					3.1	6.3	0.5	0.33%	0.025	6.8	181	
C#4	RR tracks N of Sunset Rd & W of Byron Hwy		M&A, 1998	cmp	24					3.1	6.3	0.5	0.33%	0.025	6.8	181	
C#5	Sellers Avenue north of Sunset Road		M&A, 1998	concrete pipe	21					2.4	5.5	0.4	0.25%	0.015	6.9		
C#6	Sunset Road west of Eden Plains Road		M&A, 1998	concrete pipe	21					2.4	5.5	0.4	0.33%	0.015	7.9		
C#7	Byron Highway south of RR tracks		M&A, 1998	culvert									0.42%				
C#8	RR tracks south of Sunset Road		M&A, 1998	culvert									0.33%				

* Culvert Capacity estimates assumed the culvert was clear of any accumulated sediment

Knightsen Topography: Drainage Ditch

Label *(see map)*	Location	distance (m)	Source	Description	Diameter (in)	Exposed* (in)	Le
	Delta Road Ditch:						
XS#5		3700	PWA survey	no ditch			
XS#4		2865	PWA survey	Triangle			
XS#3		2634	PWA survey	no ditch			
	Ohmstede Road	2617	PWA survey	culvert	12	7	5
	2500 Delta Road	2080	PWA survey	culvert	20	12	3
		2035	PWA survey	culvert	24	15	2
XS#2		1972	PWA survey	Triangle			
		1952	PWA survey	culvert	12	0	
		1777	PWA survey	culvert	19	13	2
XS#1		1429	PWA survey	Triangle			
C#2	at Byron Highway	1208	PWA survey	cmp	30	13	
	3091 Delta Road	1081	PWA survey	culvert	18	12	2
		876	PWA survey	culvert	10	10	1
	Mercer Avenue	806	PWA survey	culvert	15	12	
XS#8		787	PWA survey	Triangle			
	3319 Delta Road	730	PWA survey	concrete	18	8	
XS#7		381	PWA survey	Triangle			
		340	PWA survey	culvert	32	26	2
XS#6		36	PWA survey	Triangle			
	Byron Highway Ditch:						
XS#15		1396	PWA survey	no ditch			
	8560 Byron	810	PWA survey	culvert	18	12	5
XS#14		696	PWA survey	Triangle			
	8476 Byron	575	PWA survey	culvert	10	10	2
	8160 Byron	275	PWA survey	culvert	18	4	3
XS#13		101	PWA survey	Triangle			
	Power Tower Ditch:						
XS#9		50	PWA survey	Parabolic			
C#9		370	PWA survey	pipe	60	42	2
XS#10		425	PWA survey	Parabolic			
C#10		959	PWA survey	pipe	60	49	3
XS#11		996	PWA survey	Parabolic			
C#11		1497	PWA survey	pipe	60	48	2
XS#12		1799	PWA survey	Parabolic			
	Others:						
C#1	Delta Rd, west of RR tracks	3244	PWA & M&A, 1998	pipe	24	0	
C#3	Eden Plains Rd S of RR tracks		M&A, 1998	cmp	18		
C#4	RR tracks N of Sunset Rd & W of Byron Hwy		M&A, 1998	box			
C#4	RR tracks N of Sunset Rd & W of Byron Hwy		M&A, 1998	cmp	24		
C#4	RR tracks N of Sunset Rd & W of Byron Hwy		M&A, 1998	cmp	24		
C#5	Sellers Avenue north of Sunset Road		M&A, 1998	concrete pipe	21		
C#6	Sunset Road west of Eden Plains Road		M&A, 1998	concrete pipe	21		
C#7	Byron Highway south of RR tracks		M&A, 1998	culvert			
C#8	RR tracks south of Sunset Road		M&A, 1998	culvert			

* Culvert Capacity estimates assumed the culvert was clear of any accumulated sediment