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# Hydrologic Investigation of Concrete Flood Control Channel at UC Berkeley's Richmond Field Station

**Courtney Davis & Patrick Nichols**

**Abstract** The Richmond Field Station Natural Restoration Project is a five-year, multimillion dollar effort by the University of California to remedy polluted marsh lands, restore upland prairie habitat, and to convert a concrete flood control channel into a free flowing creek and riparian corridor. Historically no creek existed here so the dynamics of this concrete drain system must be understood to properly design a new channel. This study assesses multiple aspects of the concrete channel to determine the health(assessed using EPA standards) and qualifications for restoration. We measured flow at various intervals along the channel using velocity observations and cross sectional areas, developing a stage-discharge relationship. On a weekly basis for three months during the winter/spring of 2004 we measured water quality characteristics: dissolved oxygen, turbidity, and conductivity. This information addresses the question of what the hydrological characteristics are for this unique system and the health of this system with regards to these variables. The channel had a consistent base flow of about 1 cubic foot per second (cfs) over the period of January 2004 to April 2004 with a peak flow around 152cfs. A linear relationship exists between depth and flow. The slope of the channel water surface is about 0.36%. The water quality parameters were indicative of a healthy system. The results of this project provide baseline knowledge for future investigations.

## Introduction

Anthropogenic activity has had irreversible affects on almost every watershed system in the United States if not the world (The Federal Interagency Stream Restoration Working Group, 1998). It has been known for some time that human influences have enormous impacts on these systems. "Human activity has profoundly affected rivers and streams in all parts of the world, to such an extent that it is now extremely difficult to find any stream which has not been in some way altered, and probably quite impossible to find any such river Hynes (1970)." This holds true for most water bodies, especially estuaries and bays with large metropolises relying on them like the San Francisco Bay. It has been estimated that the bay is only two-thirds the size it was before European descendents began damming, diking and filling (Save The Bay website, 2004). Since the seventies there has been an increasing movement to protect and restore the vital habitat of the urban streams, their riparian corridors, and associated wetlands (Schwartz, 2000).

The UC Berkeley owned Richmond Field Station (RFS) in Richmond, California just north of Berkeley (see location map appendix A), is the center of a five-year remediation and restoration plan. The plan is centered around Stege marsh, and addresses property partially owned by UC Berkeley, East Bay Regional Parks, and a private brown-field development company (A. Moore, University of California, Berkeley, personal communication, November 2003). The marsh has had a long and complex history of pollutant loading (URS Greiner *et al*. 1999). Cinder pyrite dumping combined with the sedimentation from the watershed and creation of jetties long ago converted a former mudflat into a tidal salt marsh. The marsh, now known as Stege Marsh, was loaded with toxins from a combination of by-products from the mercury fulminate facility and the explosive and industrial chemical production located there. In 1997, the area was designated a toxic hot spot by the Bay Protection and Toxic Cleanup Program, which mandated a clean up by the property owners. The concentrations of many pollutants in the marsh were higher than EPA standards, by several orders of magnitude, such that it required a major operation to remediate the toxic conditions. The University chose to remediate and restore the marsh in order to create and preserve some optimal habitat for many species including the endangered Clapper rail (*Rallus longirostris obsoletus*) and salt marsh harvest mouse (*Rerthrodontomys raviventris*).

Stege Marsh, bordered by a portion of upland prairie habitat also being restored, has three fresh water inputs and tidal influence from the San Francisco Bay. One of the fresh water sources, Baxter creek, enters from the southeast. On the northwest side there is Meeker creek and an unnamed concrete lined channel (S.Farrell, Aquatic Outreach Institute, personal communication, November 2003). This trapezoidal concrete lined flood control channel runs adjacent to a large portion of the upland prairie habitat slated for restoration, and is the focus of this research. The long-term restoration plan for the property includes restoring this channel to a "natural" creek setting using and demonstrating various bioengineering technologies that have been successful at restoring riparian habitat (Nolan & Guthrie 1998). This "natural" creek restoration is unique because it essentially would create a creek where there was not one historically. The riparian habitat would transition to the adjacent upland prairie habitat and into the marsh and slough area.

At the beginning of this project very little was known about this channel, except that it appeared in historical aerial photographs around the 1940's, and did not exist before then. The planners knew nothing about its exact origin, its flow rate, capacity, water quality etc. (S.Farrell, Aquatic Outreach Institute, personal communication, November 2003).

The objectives of this study were to measure discharge and sample water quality in the channel at regular intervals over the 2004 winter-spring runoff period, to survey channel geometry, characterize the hydrology, water quality, and channel form to inform efforts to "restore" this channel to a more natural condition. The system can then be analyzed for ecological health according to the EPA standards for dissolved oxygen, conductivity, and pH for creek systems in this region (EPA Website, 2004).

With this information a restoration plan for the creek can be devised and implemented in the years to come. These different parameters are extremely important to know, especially flow rate, volume, and water quality in order to understand the dynamics of the creek and create the optimal vision for restoration (Kondolf 1990). Every hydrological system is unique in so many ways that it is very important to discover everything possible about the system before devising a plan to transform it to an aesthetically more natural setting (Kondolf 1998).

## Methods

Our baseline data collection, as recommended for any stream restoration project by the Federal Interagency Stream Restoration Working Group (1998), involved: (1) acquiring maps of the channel and all the storm drain connections to determine the size and location of its drainage basin, (2) taking flow rate/volume measurements after key storm events and throughout winter/spring 2004 to document its flow regime, (3) conducting hydrologic level surveys based on Dunne and Leopold (1978) and Gordon *et al.* (1992) and (4) simultaneously documenting some water quality parameters at selected points along the creek: (a) measuring conductivity because it is very important to the salting out effect of nutrients at the freshwater/saltwater interface; (b) turbidity and (c) dissolved oxygen; d)recording pH, temperature, and salinity because of their impact on the types of biota that can survive in the water once restored (Horne & Goldman, 1994). We chose three sites along the concrete channel to collect flow and water quality data. We collected data randomly through February, March, and April 2004. We sampled at three sites: one where the channel surfaces from an underground culvert, one along the main stem of the channel and one near the mouth of the channel where it empties into Stege marsh (see sketch map appendix A). We conducted a level survey to measure the slope of the land and water surface required for estimating channel flow and designing creek form.

We performed the following data collection:

- Using the storm drain/flood control maps, and topographic information in conjunction with the hydrological data, we calculated the drainage area and land use for the catchment of this channel. We used this data to estimate peak flows of the major storm events that only occur at various long-term intervals (i.e.: 50 and 100 year flood events).
- Measuring flow data over ten weeks and around big storm events, avoiding times when tides were high enough to affect the channel. This provided data at the three sites for each collection time. We measured velocity, using orange

peels, and multiplied by the cross-sectional area (Dunne & Leopold, 1978). See appendix A for calculations.

- We measured six important water quality parameters: pH, turbidity, dissolved oxygen, temperature, salinity and conductivity using a Horiba U-10 water quality multi-meter.
- We surveyed a longitudinal profile using a surveyor's level and rod at 100m intervals including thalweg and water surface.
- We surveyed three channel cross sections at the sites of flow measurement and water quality sampling.

The flow data was averaged over the three sites as replicates then plotted by time to show the pattern of flow during the course of the study, and also for assessing average and peak flows (Dunne & Leopold, 1978). We plotted average flow by the amount of rainfall within 24 hours of data collection, estimated from precipitation data on the NOAA website (2004), in order to understand how the watershed responds. We also plotted the average depths with their associated average flows creating a rough rating curve for the system, so the channel can be gauged and the gauge height (depth) used to easily infer the flows in the future. We used the distributions, including the means and standard deviations of the water quality parameters, for comparison to expected EPA standards associated with systems in this area as a preliminary proxy for potential ecological health (EPA website 2004), see table 1. We estimated peak flows following the Rantz method (1971) derived from drainage basins from 0.2 to 196 mi$^2$ with average precipitation from 13 to 60 inches, 2-year floods ranging from 5 to 27,000cfs located in the San Francisco Bay area. This system fits into all of these categories. For comparison peak flows we also estimated peak flows using the Rational Method (Dunne & Leopold, 1978), which is not recommended for basins larger than 200 acres like this one (see appendix A for all calculations).

## Results

We estimated the drainage area using a storm drain map from the city of Richmond. This map yielded a drainage area of approximately 1,624 acres (2.54 square miles), see appendix A. The maps also showed us that the land use of the drainage area is approximately 50% industrial and 50% residential. The average annual rainfall is 23.19 inches (Western Regional Climate Center, 2004). We used this information to calculate approximations for expected peak flows. In order to get a representitive range of possibilities we estimated peak flows with the Rational Method and Rantz method, the latter of which is most applicable to this type of system. The Rantz method estimated peak flow for the 2-year storm around 104cfs, the 10-year storm around 369cfs, and the 50-year storm a peak around 824cfs. The Rational Method estimated a peak flow for the 10-year storm around 892cfs, around 1137cfs for the 50-year storm, and a peak flow around 1223cfs for the 100-year storm. See appendix A for all calculations.

The surveying concluded that the channel has a slope of approximately 0.36% with a length of 1660.21ft from the culvert opening to the point where it meets the marsh. The cross sections show a uniform shape over most of the channel (appendix A). The long profile reveals the channel does not slope evenly and flattens out in places creating deeper water, which we observed when walking the channel (fig 1).

The flows peaked out at 153 cfs during the largest storm event of the season (fig. 2). Pre-wet season observations show that this system seems to have a consistent base flow of approximately 1 cfs (fig. 2).

We observed a strong correlation between the depth of the water and the flow (fig 3). This made it possible to apply a linear regression as an approximate rating curve. Once gauged, flow can be estimated using the linear formula: Average Depth (in) = 3.9165667 + 0.1415054 Average Flow ($R^2$: 0.84).

We made numerous visual observations of the channel through the course of our study including, sighting an unidentifiable fish in the channel. We also observed many waterfowl using the channel for refuge, we heard frogs or toads of some sort, and we saw what appeared to be amphibian eggs. During the spring, the channel exploded with submerged and emergent vegetation and algae

The temperature ranged from 12.7°C – 17.9°C with a mean of 14.4°C. The pH averaged 7.65, which is about neutral (7), indicating no acidic or alkaline problems. The dissolved oxygen (DO) averaged 9.19mg/l with a standard deviation of 2.20 mg/l. Conductivity was in the expected range with a mean of 0.239 mS/cm and a standard deviation of 0.136 mS/cm. The turbidity had a wide range of variance, and increased greatly during high flows, as expected. The max was 125 NTU during the largest storm event and during the low flow it got as low as 2 NTU. The average was 61.6 NTU with a standard deviation of 48.2 NTU. Salinity was quite low throughout the study as expected for a fresh water system. All values shown in table 1.

## Discussion

The data suggests that this could be considered a healthy system according to the guidelines set by the EPA with respect to pH, conductivity, and dissolved oxygen as seen in table 1. Although lined with concrete, this channel does not seem to have any major problems with these simple water quality parameters when compared to expected EPA standards for a system of this type and area. Temperature and salinity do not appear to be beyond any thresholds for biota (Horne & Goldman 1994). Having a constant base flow is very important for a riparian system, this system appears to have a base flow around 1 cfs during the wet season. This base flow divided by drainage area gives a unit runoff of 0.39 cfs/mi$^2$ which does not seem unreasonable when compared to Wildcat Creek, a restored system in north Richmond, which had a unit runoff of 0.47 cfs/mi$^2$ in 1994 (a relatively dry year) and a unit runoff of 1.3 cfs/mi$^2$ in 1995 (wet year) (USGS 1995). Already supporting an apparently healthy ecosystem, with thriving aquatic biota and avian presence, this channel appears as though it could be successful as a stream corridor. During the study we observed the channel exploding with submergent and emergent vegetation and algae during the spring. We observed many waterfowl using the channel for refuge, as well as a few small fish. We heard frogs or toads of some sort and saw what appeared to be amphibian eggs. The fact that this channel already has a thriving aquatic ecosystem implies that it would be a great candidate for riparian creation. It should also be noted that while this study focused on the system as a fresh water input to the salt marsh, so we took no measurements of tidal effect, we observed the tide from the bay influencing the channel over 740 feet up from the marsh, indicating that a section of the channel is part of the tidal marsh itself.

Due to the limitations of the equipment, we could not attain various water quality parameters, such as nitrogen, phosphorus, and heavy metal levels that are important to the successful restoration of the system (TFISRWG 1998).

The data collected provides a graphical representation of the flow dynamics during the 2004 winter-spring season as the first analysis of the hydrologic character of the channel. The quality of this system can not factually be determined by these results, as it is extremely limited by only being collected during one wet season, and the enormous variability's both seasonal and yearly, of stream systems (Dunne & Leopold, 1978). We can use this season as a proxy for an average season, and a first step in the complete analysis spanning many years.  This certainly does not produce the most accurate representation possible, as a flow meter and/or hydrological gauge permanently placed in the channel could collect continuous flow data and give you the exact flow dynamics of the system.  The data definitely provides an insight to the dynamics and a starting point for further collection of data in order to devise a unique restoration plan specifically for this system.

The flow plotted by the rainfall fallen in the area within 24 hours of the data collection (NOAA Weather Page, 2004) shows a quick response to precipitation and high discharge associated with less than 2 inches of rain (fig. 5).

This association could be better explained with the installation of an onsite rain gauge, and a stage gauge in the channel recording continuously. The water quality parameters indicate that this is a healthy stream with respect to the variables collected in this project according to the EPA (EPA Website 2004). The large variation in turbidity is explained by its association with flow. It is expected that larger flows during storms carry more sediment (fig. 6). We observed very little sediment in the channel so we must assume it is all being carried to the slough and marsh where it is deposited.

## Conclusion

This channel should be considered a good candidate for restoration with respect to the parameters we investigated (See table 1). The baseline data collected in this study will hopefully be used for future research of the system including multi-year discharge analysis and quality characterization; however, this baseline data collection is just a small piece of the puzzle because it only represents the channel during the small snap shot in time during which we sampled.

More research is needed on this system before any project can begin. Further water quality indicators should be tested such as nitrogen, phosphate, heavy metals, and PCB levels, etc. Monitoring should be continued to get a more accurate representation of the flow dynamics over the course of many years. Installing a stage gauge and an onsite rain gauge so the depth could be monitored 24 hours a day would also aid in documenting flow for all events in the system for long time assessment.

This project may go well beyond the scope of this school year as it will need quite a large amount of energy and time to complete the restoration/creation of the creek, and the marsh is not scheduled to be completely remediated for another 3-4 years. We were lucky enough to get involved at the beginning of the data collection of the channel, but we are hoping to be involved beyond this study and the baseline data collection to someday see the channel created in to a man-made 'natural' creek with riparian habitat.

## Figures & Tables

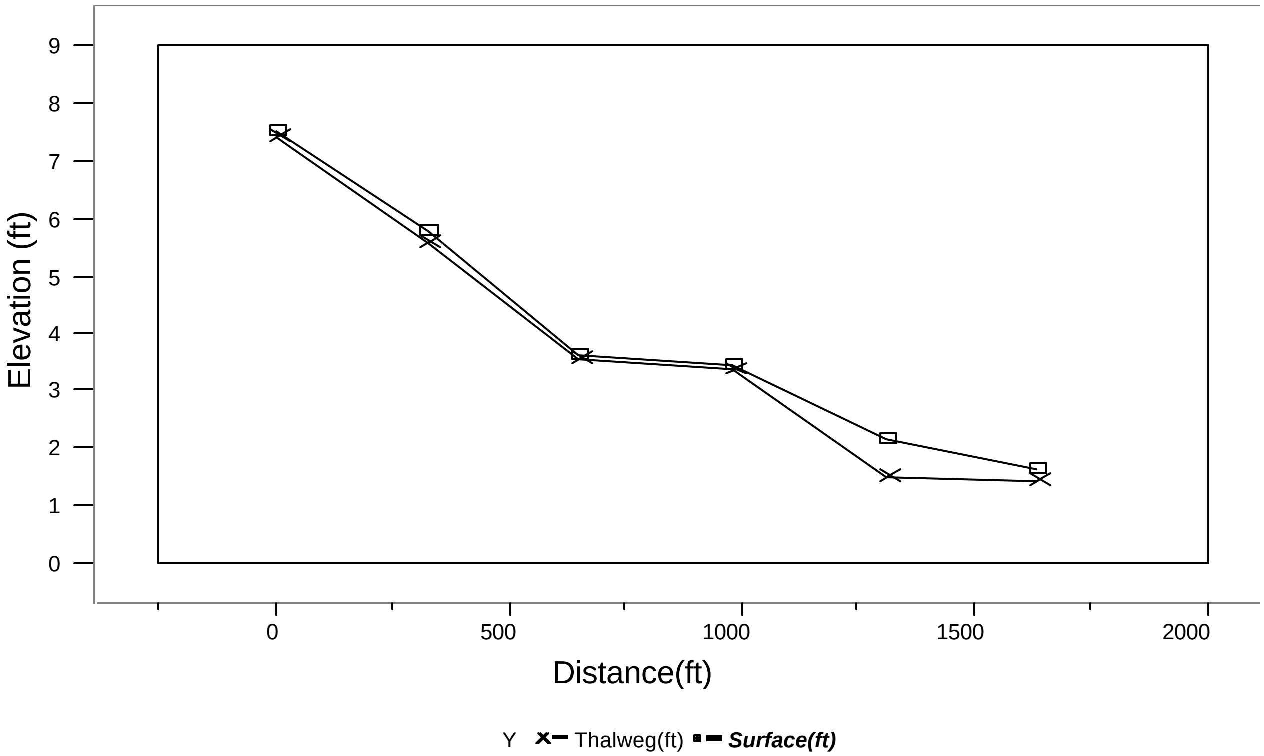

Fig. 1: Longitudinal Profile

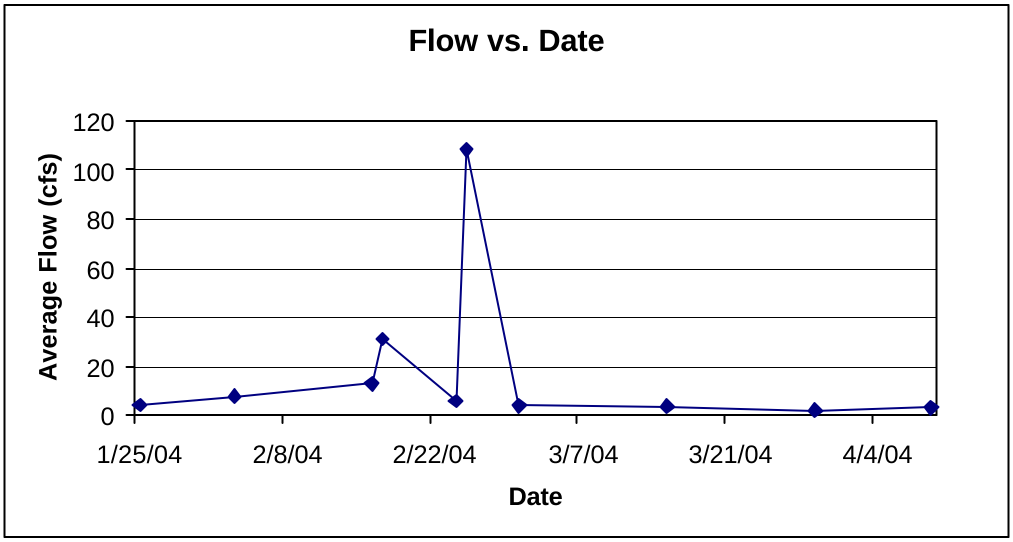

Fig. 2: 2004 winter-spring season hydrograph

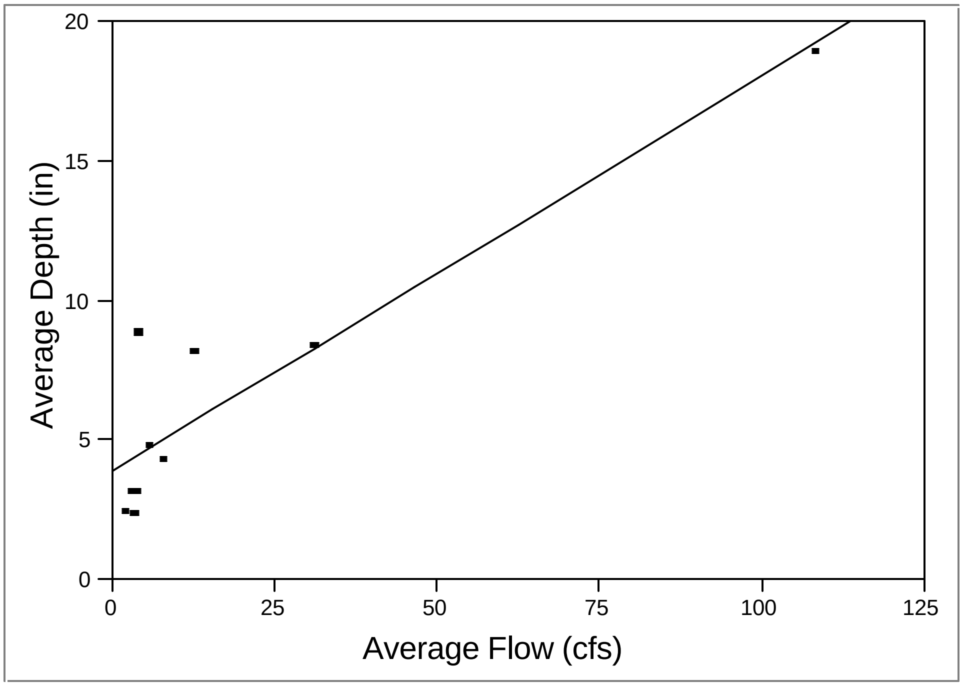

Fig. 3: Rating Curve, Linear Fit of Depth (in) by Flow (cfs)

| Parameter | pH | Conductivity (mS/cm) | Dissolved Oxygen (mg/l) | Turbidity (NTU) | Temperature (º C) | Salinity (%) |
|---|---|---|---|---|---|---|
| Mean | 7.9 | 0.371 | 11.7 | 61.6 | 15.8 | 0.017 |
| Std. Dev. | 0.78 | 0.172 | 3.90 | 48.2 | 2.92 | 0.029 |
| EPA Standard | 6 –to- 8 | 0.150 –to- 0.5 | 9.65 –to- 10.76 | NA | NA | NA |

Table 1: Water quality parameter means and standard deviations with EPA standards when applicable.

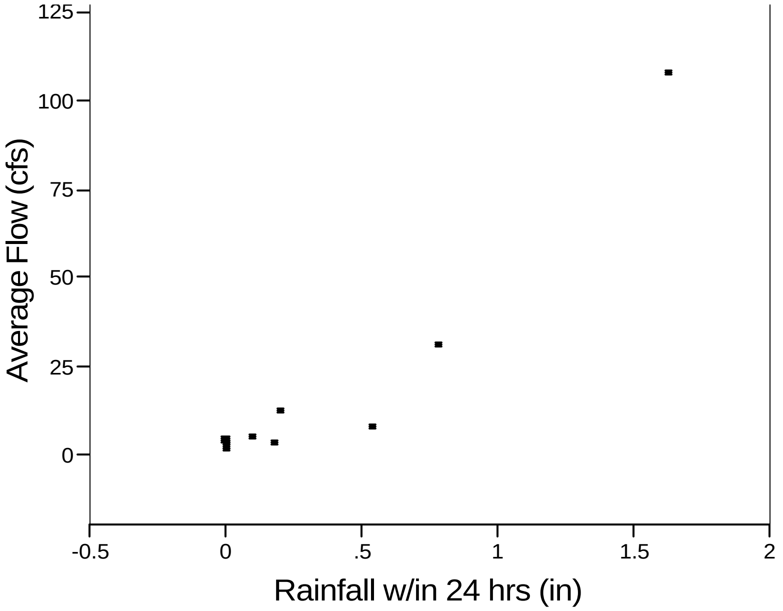

Fig 5: Average flow response to rainfall w/in 24 hours

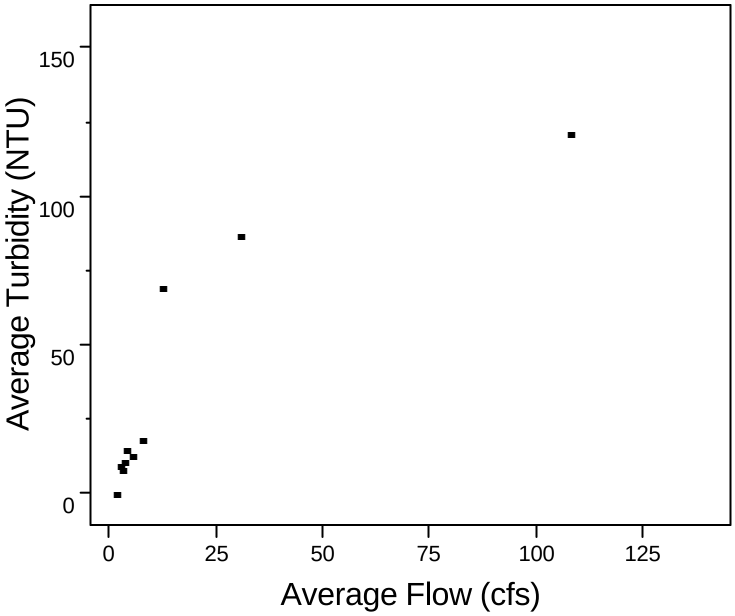

Fig. 6: Turbidity explained by discharge.

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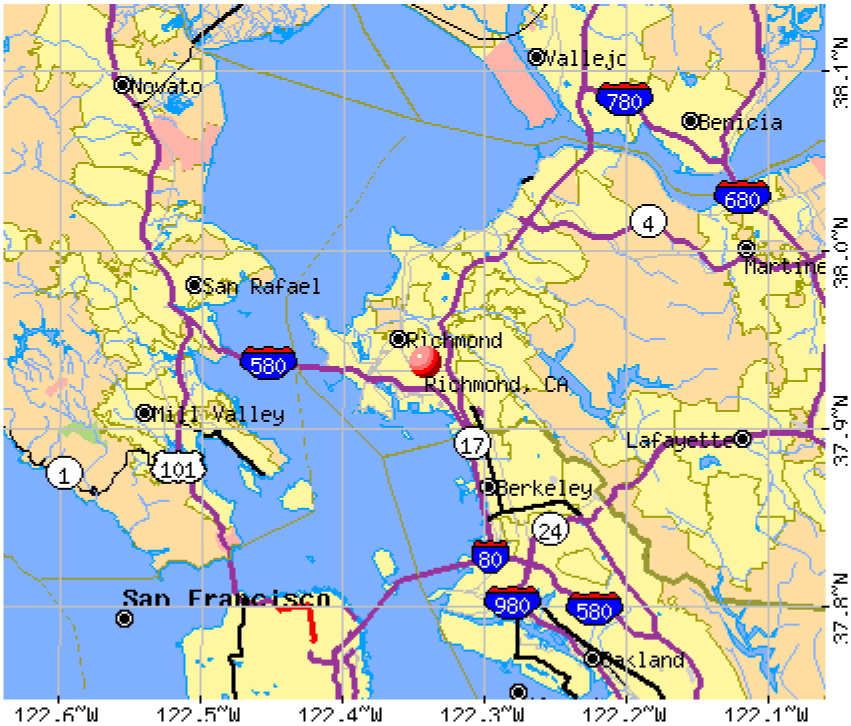
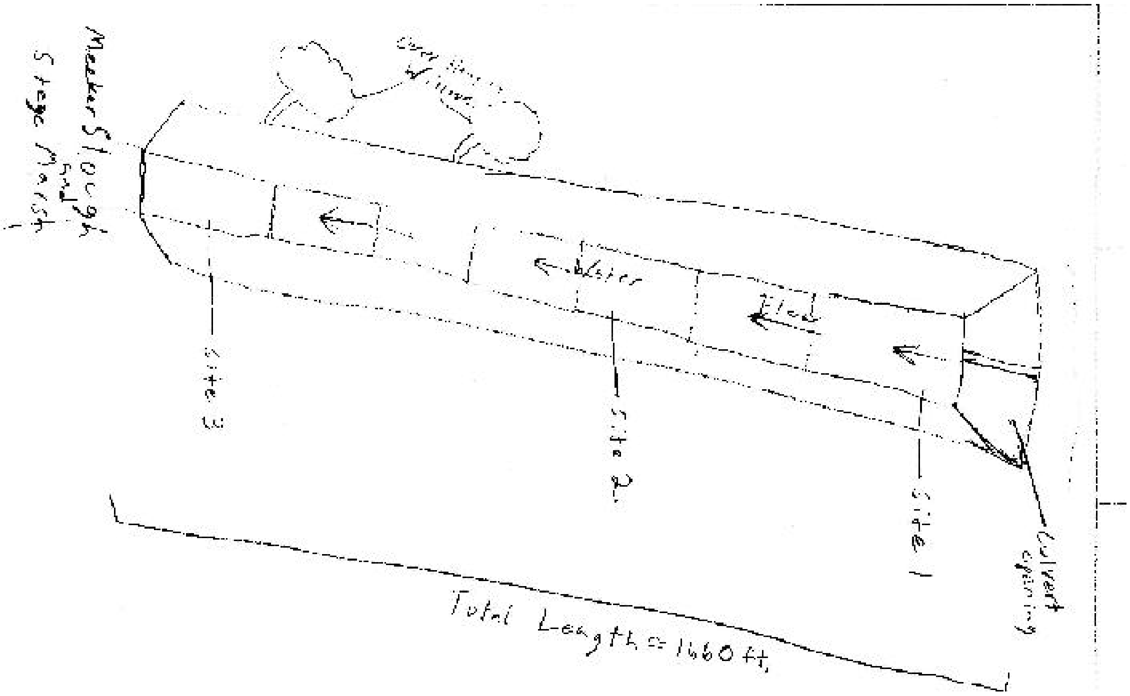
## Appendix A: Maps



Location Map courtesy of City Data.Com



Sketch Map

## Appendix A: Calculations

Average Flows estimated by timing velocities of orange peels over a known distance and multiplying by the cross sectional area estimated from the graphed cross sections and measured depths using equation Q(flow in cfs) = V(velocity in ft/sec) * A(cross sectional area in $ft^2$):

| **Date** | Upper Reach (cfs) | Middle Reach (cfs) | Lower Reach (cfs) | Average Flow (cfs) | Rainfall w/in 24hrs (in) |
|---|---|---|---|---|---|
| 1/25 | 2.75 | 3.87 | 6.09 | 4.24 | 0 |
| 2/16 | 7.5 | 9.50 | 21.2 | 12.7 | 0.2 |
| 2/17 | 20.72 | 29.7 | 42.9 | 31.1 | 0.78 |
| 2/3 | 3.61 | 9.40 | 10.6 | 7.87 | 0.54 |
| 2/24 | 9.28 | 4.25 | 3.60 | 5.71 | 0.1 |
| 2/25 | 131 | 106 | 87.9 | 108 | 1.63 |
| 3/1 | 4.23 | 3.92 | 3.58 | 3.91 | 0.18 |
| 3/15 | 3.58 | 2.41 | 4.76 | 3.58 | 0 |
| 3/29 | 1.74 | 2.02 | 1.95 | 1.90 | 0 |
| 4/9 | 1.5 | 2.73 | 4.83 | 3.02 | 0 |

WaterShed Estimates were done using a storm drain network map from the City of Richmond Department of Public Works Division of Engineering.
Scale: 1 inch = 400 feet
Drainage Area: on map = 442 $in^2$ = 7.07 $e^7$ $ft^2$ = 1624 acres = 2.54 $mi^2$
Land Use: 50% Industrial 50% Residential
Average Annual Precipitation: 23.19 in

Peak Flow Estimates:
Haltiner's Order of Magnitude ~ $Q_{100}$ (cfs) = (0.5-to-1.0) (drainage area in acres)
$Q_{100}$ = (0.5-to-1.0) (1624 acres) = 812 cfs –to- 1624cfs
Rantz Method ~
$Q_2 = (0.069)A^{0.193}P^{1.965} = (0.069)(2.54^{0.193})(26.9^{1.965}) = 104$ cfs
$Q_{10} = (7.38)(2.54^{0.922})(23.19^{0.928}) = 369$ cfs
$Q_{50} = (69.6)(2.54^{0.847})(23.19^{0.511}) = 824$ cfs
Rational Method ~
Concentration time (Dunne & Leopold) $t_c = L^{1.15}/7700(H^{0.38})$
L = 15100 ft
H = 300 ft
$t_c$ = 0.95 hr ~~
Rainfall intensity I (in/hr) from Rantz (1971)
$I_{10} = 0.785$
$I_{50} = 1.0$
$I_{100} = 1.075$
Rational Runoff Coefficient C from Dunne & Leopold (1978)
C = 0.70

Rational Method Equation

$$Q\ (\text{cfs}) = C\ I\ A$$

## Appendix A: Calculations continued

Rational Method Computations

$$Q_{10} = (0.70)(0.785)(1624) = 892 \text{ cfs}$$
$$Q_{50} = (0.70)(1)(1624) = 1137 \text{ cfs}$$
$$Q_{100} = (0.70)(1.075)(1624) = 1223 \text{ cfs}$$

## Appendix A: Cross Sections

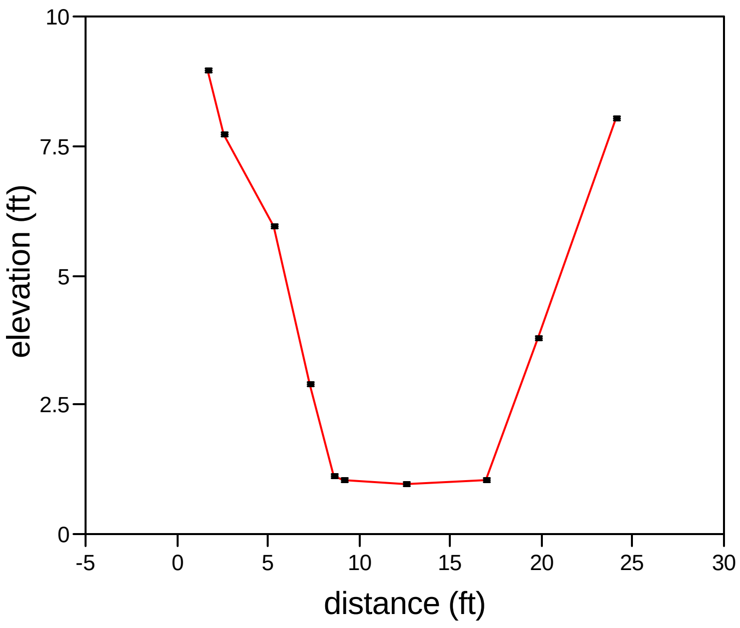


Fig. 1: Cross Section at Site 1

## Appendix A: Cross Sections Continued.

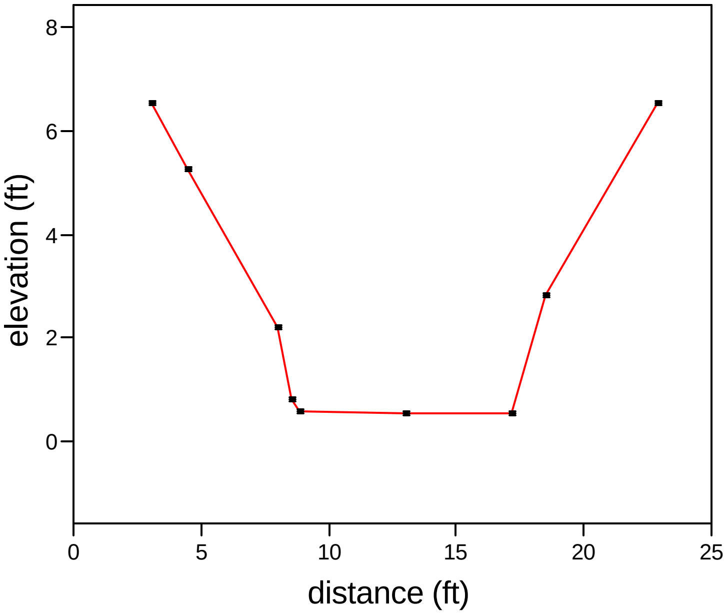


Fig. 2: Cross Section at Site 2

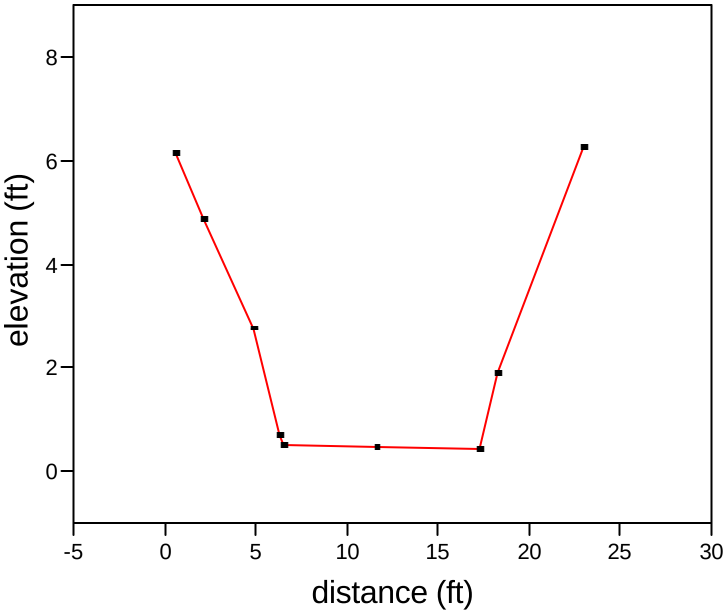


Fig. 3: Cross Section at Site 3.