ROSE CREEK HARDSCAPE

NATURALIZATION PROJECT

by

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ABSTRACT

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By Christopher E. Oesch

Environmental Systems: International Development Technology

The Rose Creek Hardscape Naturalization Project (RCHNP) will address the feasibility of improving wetland function, stream integrity and reconnection of the wildlife corridor within concrete channelized sections of urban waterway, also known as "Hardscape" channels. The RCHNP will remediate these negative effects by "naturalizing" the area within the existing hardscaped channel. This approach will use an integration of biology and engineering practices commonly used for enhancing stream habitat in natural landscapes of the Pacific Northwest and around the country, as well as newly developed concepts specific to the Rose Creek location. These methods will involve the addition of permanent structures to create a varied flow regime, and the introduction of wetland plants into the hardscape channel, creating shade, slowing the water, and encouraging sediment and organic matter deposition in key locations. This will promote reconnection of previously segmented watercourse habitats. All hardscape structural additions will be engineered to remain secure during peak stormflow events without promoting flooding above the hardscape channel walls.

The practice of hardscaping in urban streams has been successful in addressing human need and urban development, however is negligent in addressing the long-term
health of the watercourse, including its native fish and wildlife populations. The RCHNP seeks to address this habitat marginalization without disruption of human and urban needs.
PREFACE

Currently, the Rose Creek Hardscape Channel is visually ugly at best. In my first sighting of the Rose Creek channel in January 2000, it was mentally written off as a drainage ditch. As one exits at Pacific Beach from I-5 South in San Diego, California, Rose Creek winds out of a Riparian zone, and starts across the hardscape channel. During low to medium flows, the water spreads out in a thin sheet, speeding solar warming and evaporation. The moistened concrete bottom readily grows algae, streaking the channel brown. Aside from this, the only other visually notable features are trash and graffiti.

During my time in San Diego I became involved with The Nature School, a non-profit environmental restoration program focusing on rehabilitation of natural habitats in Rose Creek Watershed. As I talked with The Nature School’s founder, Dr. Robert LaRosa, about his plans and visions for the Rose Creek Watershed, I became interested in what was to be done with the 700 foot long, 100 foot wide concrete hardscape channel.

I remained in contact with Dr. LaRosa while pursuing my graduate degree at Humboldt State University. The idea of landscaping inside an existing concrete channel interested me very much. As I researched the idea more, I discovered a total absence of literature on the subject of hardscape naturalization. When I shared this finding with Dr. LaRosa, he encouraged me to explore the topic further. With the academic guidance of
Dr. Dan Ihara and Dr. Robert Gearheart I have focused my graduate studies in a way which will enable me to participate in the currently emerging field of urban wetland restoration.
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NOMENCLATURE AND DEFINITIONS

**Baseflow**: Year round continual water flow. Baseflow usually refers to groundwater sources, but more generally means non-precipitation induced streamflow.

**Berm**: A raised bank or mound used for streamflow deflection.

**Duration**: In this context referring to the time length of a precipitation event.

**Frequency**: In this context referring to number of times a precipitation event of a certain magnitude occurs within a given time period.

**Geomorphology**: The study of landforms and the processes which create them.

**Hardscape**: Term used in landscape architecture and environmental engineering which refers to man-made paved, concrete, brick, stone or metal structures.

**Hydrology**: Study of properties and effects water has on the earth’s surface, within soil, and in the atmosphere.

**Magnitude**: In this context referring to the amount of precipitation from a given storm event.

**Riprap**: Placement of loose rock or concrete pieces along the bank of a stream to prevent erosion.
Stormflow: Amount of water passing through a given section of stream channel at peak level from a precipitation event. Stormflow is also known as peakflow or quickflow.

Transport Rate: Velocity of water at which a particle of a given size is suspended and carried with the flow of water. Slightly more velocity is needed to initially suspend a particle than is needed for the particle to remain suspended.

Urban Channelization: Refers to altering of a stream’s natural path as it flows through urban areas. This can include changing its course, grade, channel structure, channel material or in any other way interfering with natural fluvial processes.

Watershed: Geographic basin in which any precipitation occurring within it’s boundary will empty into the same body of water.
1.0 INTRODUCTION

1.1 Rose Creek Hardscape Channel

The term “hardscape” refers to any man-made paved, concrete, brick, or stone structures. It is a term common to landscape architecture design, and has been used by Robert La Rosa of The Nature School in San Diego, California to describe the concrete channel in Rose Creek.

The Rose Creek Hardscape Channel is located in San Diego, California (see figure 1.0). As one exits I-5 South onto Mission Bay Dive, the hardscape channel is visible to the left. The hardscape channel itself is a cement structure, 100 feet wide, 700 feet long, making a 45 degree bend in the lower third. It has a flat bottom, vertical sides, and has 4 “fin” walls going with the length of the creek located in the bend to keep stormflows from pushing exclusively on the outside wall of the bend. This reduces strain on the outer wall (see figure 1.1).

In meeting public demand for flood control protection, civil engineering of the past century emphasized hydrologic constraints, including concrete and riprap channeling of urban waterways. While successful in reducing the risk of flood, hardscaped channels disable natural wetland and hydrologic function needed to protect water resources. Thousands of miles of coastal habitat have been altered in this way. Effects on water quality and the health of native fish and wildlife has been catastrophic.
Figure 1.0 Location of Rose Creek Hardscape Channel in San Diego, California. Adapted from SanGis, City and County of San Diego.
Figure 1.1 Rose Creek Hardscape Channel. Adapted from SanGis, City and County of San Diego. (Drawing by Christopher E. Oesch).

During the middle part of this last century, channelizing urban waterways with concrete became a widely used method of dealing with naturally occurring watercourse meander and flooding in populated areas. Hardscaped channels disrupt wildlife habitat and natural hydrology in three ways.

First, hardscaped channels alter the hydrology of the stream by speeding up water as it flows over the smooth bottom surface. In a natural watercourse, surface irregularities on the bottom, such as rocks, logs, and surface depressions create drag, slowing down the water. This causes variation in water speed throughout a given cross
section of the channel. In faster locations, sediment and organic matter become suspended, settling back out once the water drops below transport rate. A natural channel self regulates in this way. However, as water passes over a hardscaped area, the lack of surface irregularities does not allow suspended particles to settle out within the channel. This results in an abnormally large particle deposit directly downstream of the hardscaped area.

Second, the increased flow rate can prevent aquatic life from moving upstream against the current, thereby effectively cutting off upstream habitat. The fast moving water discharging from the hardscape has more energy with which to effect the downstream area. Therefore, erosion and bottom scouring increases, which strains plant roots, and removes naturally deposited habitat-enhancing debris.

Third, because of the lack of riparian tree cover, and high thermal conductivity of concrete, water passing through hardscaped areas becomes heated by solar radiation to temperatures that are deleterious to native aquatic species. As water temperatures increase, dissolved oxygen (DO) levels decrease. Cooler water can store more dissolved oxygen than warmer water (Brooks et al. 1997). As water temperatures increase, microbial activity increases, thereby raising oxygen demand. This further reduces the amount of DO available for fish, amphibians and other aquatic animals.

To the best of the author’s knowledge at present time, this is the first extensive project design, specifically for in-hardscape urban channel modification. Current literature on urban watershed restoration has promoted total removal of hardscape
channels. This is a more direct step towards remediating the negative effects of urbanization on the watershed, one which this paper does not challenge. This paper presents another alternative, for when hardscape channel removal is not practical or possible, and stream habitat “naturalization” is desired.

1.2 History of Rose Creek

Rose Creek feeds into Mission Bay in San Diego, California. This watershed contains riparian, coastal marshland, fresh and brackish water habitats. Rose Creek’s current location is not its original path. In the early part of this past century, it flowed through what is now the Pacific Beach community. As this location became more attractive for development, and the high market value for land was realized, Rose Creek was diverted into Mission Bay via the shortest route possible (La Rosa 2002).

Mission Bay itself is not a true bay, but was originally coastal marsh. During the late 1940’s and 1950’s, the marsh was dredged, and the lifted sediment was used to create islands and to define the perimeters of the new “bay”. This enhancement of definition between water and land was more useful for development purposes, as it created dry ground solid enough to urbanize (La Rosa 2002).

This mentality of separation between water and land also caused modification in Rose Creek. The current Rose Creek channel was almost entirely riprapped with large rocks and chunks of waste concrete to stabilize the banks. In many sections both native and non-native vegetation has obscured the riprap from view (La Rosa 2002).
1.3 Hydrologic Function

Natural hydrologic function within the hardscape channel can not begin to replicate that of an undisturbed stream (Ehrenfeld 2000, White et al. 2002). With this extreme disruption in riparian/stream continuity, natural habitat is further fragmented in an already spatially marginalized ecosystem (White et al. 2002). These smaller fragmented pockets of wetland and riparian habitat generally support fewer species and smaller populations (Ehrenfeld 2000, Savard et al. 2000, White et al. 2002, Wang et al. 2001).

1.4 Baseflow in Rose Creek

Rose Creek’s watershed is formally known as Miramar Hydrologic Unit 906.4, a sub-unit of the larger Penasquitos Hydrologic Unit. Miramar watershed drains 27,677 acres into Mission Bay (see figure 1.2) (Project Clean Water 2003).

Over time the underground springs which contributed to Rose Creek’s base flow have disappeared due to extraction for irrigation and other human uses. This has lowered the natural baseflow (White et al. 2002, Wang et al. 2001). However, due to an increase in impermeable paved surfaces, a higher percentage of water that occurs within the watershed is transported more directly into the stream channel. Urban runoff occurs from people watering their lawns, washing cars, construction, or industrial discharge (White et al. 2002). It has been shown that while an overall decline in flow from natural sources has occurred, inputs from human and urban sources have supplemented baseflow, but not to original levels. However, since human induced urban runoff does not follow
any dry or wet season trend, instead remaining consistent year round, dry season flows have slightly increased over the previously natural spring fed baseflow. (White et al. 2002, Wang et al. 2001).

1.5 Climate of Rose Creek

Rose Creek experiences a coastal Mediterranean Climate, characterized by mild temperatures year round, with dry summers and wet winters. Its proximity to the ocean further moderates temperatures. The area receives around 10 inches of precipitation annually, with the majority falling between November and March. Due to the long dry season, when streamflow levels are lowest, water quality can become very poor. Dry
season water input is primarily urban runoff which can be loaded with chemicals, metals, and pathogens (White et al. 2002, EM 1995, Wang et al. 2001).
2.0 LITERATURE REVIEW

2.1 Research Methods

Online sources used for the literature search were Ebsco scientific literature search, Omni Full-Text, Environmental Route-Net, Journal of Hydrology search, Google, and Yahoo internet search engines. The terms "urban, watershed, channel, cement, concrete, habitat, stream, coastal, enhancement, naturalization, riparian, wetland, California, hardscape, hydrology, management, runoff, and biofiltration" were used as key words in various combinations. In addition to online search resources, journals on file in the Humboldt State University library were consulted. While related projects were found, no literature was located on projects using the same components as the Rose Creek Hardscape Naturalization Project (RCHNP). Based on this search, the RCNHP appears to be the first of its kind.

Topics relating to individual components of the RCHNP were selected for the purpose of this literature review. Topics that will be discussed in this literature review are stream channel enhancement through the placement of Large Woody Debris (LWD), vegetation enhancement, urban hydrology alterations and community/urban planning issues.

2.2 Stream Channel Enhancement Through the Placement of LWD

The use of large woody debris (LWD) in stream channel enhancement efforts is a common approach (O’Neal et al. 2000). In the early and middle portion of this past century, stream maintenance involved removal of all obstructions including rock and
LWD (Aoust et al. 2000). Within the last 30 years, a drop in aquatic stream life wellbeing has been linked to the practice of removal of LWD and other stream shape irregularities according to many studies (Aoust et al. 2000). It is these irregularities which create still pools and habitat for various fish and other aquatic species (Aoust et al. 2000, Larson et al. 2001, stormcenter.net 2002).

LWD are the most common structures associated with scour pool formation in small and larger stream systems. A scour pool is a depression in the stream bed created by the process of water moving above, below or around an obstruction. This causes the flow to dig or "scour" away the channel bottom. With careful placement of LWD, a scour pool can be created in the location desired (Aoust et al. 2000, Larson et al. 2001, stormcenter.net 2002).

LWD acts as a trap for sediment and other debris. In a naturally occurring LWD cluster or "jam", there is usually one piece known as the "key member". This is typically a larger piece of LWD or rock. It is this piece which then catches smaller debris as it floats downstream, creating an ever expanding jam, until one or part of the pieces breaks free and floats downstream (Aoust et al. 2000, stormcenter.net 2002).

With all but the very largest pieces, LWD occupies its locations temporarily. Smaller LWD can be loosened and moved with seasonal peak flows, where as larger pieces can be moved with 100-year events. When designing a LWD placement plan, angle of placement in relation to streamflow is crucial. In addition, it is recommended that sufficient anchoring should be used with calculations being based on the largest know peak flow events.
A common flaw pointed out by several sources (Aoust et al. 2000, Larson et al. 2001) in LWD placement is engineering the location and anchoring based on summertime low-flow. Summer season is when many channel construction projects are started due to the calmer conditions. This can lead to movement of the LWD during storm season peak flows in stormier months (Aoust et al. 2000, Larson et al. 2001).

It has been well documented that undisturbed streams containing LWD and other surface irregularities host a more complex ecosystem than that of dredged and channelized streams (Aoust et al. 2000, Savard et al. 2000). However, there is some debate as to whether reintroducing LWD into a channelized urban stream can recreate the habitat functions that the undisturbed stream enjoys.

An extensive study was carried out in the Puget Sound Lowland region near Seattle Washington to address the rather ambiguous assumptions of the actual effectiveness of LWD in urban watershed restoration on assumed outcomes ("Effectiveness of Large Woody Debris in Stream Rehabilitation Projects in Urban Basins", Larson et al. 2001). The study concluded that while effective in improving physical habitat of the stream when engineered correctly, the addition of LWD into an urbanized stream may not specifically improve biological wellbeing or water quality. For example, if low populations in native aquatic species is the result of point sources pollution, accumulation or heavy metals, of other contamination related issues, then the addition of LWD can not be expected to mitigate these factors, and a net biological improvement will not result. It was the conclusion of this particular study, that all possible factors in urban stream degradation be taken into account, with specific
strategies to address individual issues. Given the wide range of pollutants and stressors of an urban stream setting, the study found no specific correlation between LWD placement and subsequent biological improvement. Using LWD was found not to be an effective “catch all” for general habitat improvement if non-stream morphology factors were found to be contributors (Larson et al. 2001).

While naturally occurring LWD in an undisturbed stream is not formally anchored, it was found that in order for LWD to be effective in an urban restoration setting, proper anchoring must be done. In the study, unanchored LWD washed away during peak stormflows, and thus no longer could perform their function in their intended locations. To maximize project effectiveness, it was concluded that anchoring sufficient to withstand peak events must be done (Larson et al. 2001). While not being a magical cure all for ailing urban streams, LWD has been shown in several studies (Aoust et al. 2000, Larson et al. 2001, Savard et al. 2000) to be effective in improving physical habitat of the stream when properly engineered.

2.3 Vegetation Enhancement

Literature reviewed indicated two main approaches for enhancing stream/ riparian vegetation zones. One is to eradicate any non-native species present and re-vegetate with exclusively native species. The second is to vegetate with species not necessarily native, but ones that are thought to add desired enhancing effects (Albury Group 2001).

An example of non-native plant species introduction into a riparian restoration project would be that of plants for the purpose of biofiltration. If an urban watershed is suffering from water quality degradation due to pollutants which can be dealt with
through constructed wetlands, non-native plants could be added for the purpose of biofiltration. With the correct wetland system to address specific pollutant needs, output flow from the wetland can be lower in pollutants than the input flow. Processes used in biofiltration are chemical and microbial activity to break down pollutants. Pollutant particles bind to soils and are stored in plants. This can increase the amount of stored pollutants within the wetland, creating a more toxic system. This does not provide a permanent removal, or make the pollutants “disappear”, but rather provides a temporary storage of the pollutants (Helfield et al. 1997).

Literature reviewed (Helfield et al. 1997) indicates that if the goal of the restoration project is removal of pollutants from downstream flow, then a constructed wetland for biofiltration is better suited (Helfield et al. 1997). However, if the goal is that of creating a habitable environment for native animal species, a biofiltration wetland would be detrimental to the health of native animals due to the high levels of stored pollutants. According to a study of the Don River delta in Toronto, Ontario Canada, goals of constructed wetlands and habitat enhancement efforts are mutually exclusive (Helfield et al. 1997). If your goal is to provide a hospitable environment for native plants and animals, then turning it into a pollutant storage area to create clean downstream water would work against this.

According to the habitat restoration organization the Albury Group (2001), it is preferable to encourage plants already living on site, and as a second step planting new plants of existing species. Using existing species provides habitat already familiar and with a niche in the local ecosystem to which other species do not have to adapt.
2.4 Urban Hydrology Alterations

Several studies cite that urbanization and channelization of a waterway may drastically alter the hydrology of the stream (Ehrenfeld 2000, Ellis 1995, Helfield 1997, Larson 2001, Lloyd 2000, Savard 2000, Schauman 1998). With paved areas around the waterway (parking lots, buildings, roads, etc.) soil infiltration rates are drastically reduced. This means that there is more water flowing overland and into the stream channel than would typically be seen in a non-urban environment.

According to these same sources, (Ehrenfeld 2000, Ellis 1995, Helfield 1997, Larson 2001, Lloyd 2000, Savard 2000, Schauman 1998) in a non-urban environment, precipitation is slowed on its path to the stream channel. This occurs when the precipitation is taken up by plants, or infiltrates into permeable soil, thereby temporarily storing the water. When precipitation occurs, there is a lag time between peak rainfall for a given event, and the resulting peak flow discharge of adjacent streams. However, when the majority of the precipitation falls on paved or compacted surfaces with little or no vegetative cover, it runs over-ground and into streams more rapidly, and in larger amounts from not having had much intercepted by soil and vegetation. This can mean higher and faster peak discharges (Ehrenfeld 2000).

Likewise, sources mentioned above cite that with higher and faster discharges, there is more potential energy in discharging water with which to affect the stream channel. To compound this effect, a channel that has been removed of its natural obstructions (tree snags, rocks, etc.) will allow the water to speed up even faster, having a lacking the obstructions with which to slow down flow. Literature indicates (Ehrenfeld

Ehrenfeld (2000) notes that it is common in urban stream channel alterations, their paths get straightened. This shortens the length of the stream, and changes the grade. A steepened grade can promote increased streambed erosion, as the stream will seek equilibrium and will erode down in an attempt to find its original slope (Ehrenfeld 2000).

According to several studies (Ehrenfeld 2000; Larson et al. 2001; Savard et al. 2000), water quality is another factor which is commonly altered in the process of urbanization. Densely populated urban areas contribute synthetic substances into waterways which do not naturally occur in most undisturbed stream systems (Ehrenfeld 2000). Examples of this would include motor oil, soaps, motor emissions, solvents, paints, etc. Studies indicate (Ehrenfeld 2000, Ellis 1995, Helfield 1997, Larson 2001, Lloyd 2000, Savard 2000, Schauman 1998), that if it were possible to release the same amount of these pollutants into an undisturbed, vegetated system versus an urbanized system, the undisturbed one would suffer a less intensified effect. Filtering, removing and diluting of pollutants would be able to occur, lessening concentration in the stream channel (Ehrenfeld 2000). With paved surfaces and storm drains, all the pollutants for a storm drain draw area are collected and concentrated into a point sources discharge. With many of these points existing along an urban stream channel, loading of pollutants occurs (Ehrenfeld 2000; Larson et al. 2001; Savard et al. 2000).
According to Wang et al. 2001, baseflow and ground water recharge is also altered by urbanization. Not only are higher peak flows experienced, but also lower low flows (Wang et al. 2001). While a hardscaped channel prevents water from soaking into the surrounding soil, it also prevents groundwater from helping to feed the stream in times of extreme low flows. This can promote lowflows lower than the base flow needed by some species to survive (Ehrenfeld 2000).

These concepts of urbanization are well documented, and generally agreed upon according to Mulliss et al. (1996). Given the noted hydrological function of urbanized watersheds, it is suggested that the differences are more pronounced than differences of climate zones on watercourses and a modified system of classification and evaluation should be developed to address this (Ehrenfeld 2000, Larson et al. 2001, Savard et al. 2000).

2.5 Community and Urban Planning Issues

Ellis (1995) and Rhodes (1999) observe that over the last two decades, watershed management strategies have experienced a general shift from top-down management to more local involvement both domestically and abroad (Ellis 1995, Rhodes 1999). This leads to the necessity of an “information transfer” of legal regulations, engineering, hydrology, wetland ecology, etc. to local levels.

It is the finding of Brooks et al. (1997), that many land boundaries are lines drawn on a map, without regard to watersheds. A watershed has water and gravity which are ready systems for transport. This can mean that if an action is taken in one part of a watershed, that the effects can be quickly dispersed to the rest of the watershed, thereby
effecting it (Brooks et al. 1997). In an urban setting this effect can be all the more pronounced as there are many landowners per given area, many land uses and resulting compounded effects (Wang et al. 2002).

It is universally documented that humans are agents of geomorphological change according to Ehrenfeld (2000) and Larson et al. (2001). As a species, humans have altered the face of the earth morphologically more than any other species. Attempts to understand the processes involved should be taken into account to “alter” our landscape in the most universally sustainable way possible (Ehrenfeld 2000, Larson et al. 2001). In the articles “Integrated Approaches for Achieving Sustainable Development of Urban Storm Drainage” by J.B. Ellis and “Interaction Between Scientists and Nonscientists in Community-Based Watershed Management: Emergence of the Concept of Stream Naturalization” by Bruce L. Rhodes et al., it is recommended that technical experts from outside the area should gain site specific knowledge of a given area, as to better determine the specific state of a given system. It is also recommended that separation of values and knowledge be determined to create better awareness of issue interests.

The changes urban watersheds have experienced in the last 100 years are diverse and extensive according to several studies (Ellis 1995, Rhodes et al. 1999, Savard et al. 2000). A complex new ecosystem has developed as a result, entwined with urbanization. It is suggested that in order to more effectively address this more complex system, an interdisciplinary approach be taken to address, ecology, engineering, biology, human urbanization needs (Ellis 1995, Rhodes et al. 1999, Savard et al. 2000).
2.6 Conclusion

The literature reviewed seems to be in agreement on the effects urbanization has on watersheds. Little variation was found in general concepts such as the differences between urban and undisturbed watershed function, the function of vegetation in a stream ecosystem, or the hydrological effects of stream channel irregularities.

There is a general consensus among researchers that urbanization is having catastrophic effects on the health and biological diversity of urban and coastal waterways (Ebersole et al. 1997, Ehrenfeld 2000; Savard et al. 2000, White et al. 2002, Wang et al. 2001). However, there is a lack of documentation in study of urban stream restoration methods and attempts (Bask et al. 2002, Kondolf et al. 2001, Morris et al. 1999, Meehan 1991, Rouge River Subcommittee, 1996). To move the field of Urban Watershed restoration forward, documentation and evaluation are crucial to refining practice and technique.
3.0 OBJECTIVES OF HARDSCAPE ENHANCEMENT IN ROSE CREEK

3.1 Improve Stream Hydrology

Sediment deposition.

The naturalization of Rose Creek’s Hardscape Channel will attempt to better simulate a non-urbanized stream environment, in hydrologic function, floral and faunal habitats. To create a more natural habitat for native plants and animals, Rose Creek’s hydrology will need to better mimic a non-urbanized stream (Muotka et al. 2002). Rose Creek’s smooth, flat bottom concrete channel disrupts dynamic equilibrium found in non-urbanized streams (Blanckaert 2002, La Rosa 2002). Stream channels do not remain the same over time. Fluvial processes are dynamic ones, relying on surface irregularities, or “micro-topography” of the channel to facilitate this process. It is this interaction of force (water) and resistance (topography) which create this dynamic equilibrium (Ritter et al. 2002, Brooks et al. 1997).

A fundamental interaction between a stream and its channel bed, is for soil particles to become suspended, transported by the current and to settle out down stream (Ritter et al. 2002, Brooks et al. 1997). This is an ongoing process which continually adjusts and modifies the morphology of the stream.

The Rose Creek Hardscape Channel has a smooth, flat bottom surface, unlike many non-urbanized streambeds. Without micro-topography (small surface irregularities) present in the channel, the flow pattern will be more of a “laminar flow”.
This flow regime is characterized by particles of water moving in relatively straight paths which are not disrupted by movement of neighboring particles (Ritter et al. 2002, Brooks et al. 1997).

Without micro-topography to create a turbulent flow regime, the downstream velocity increases, thereby keeping suspended particles in suspension until they pass
Figure 3.1 Illustration of a pebble cluster. The process of smaller particles settling around a larger key member, or "clast" is common with stream topographic material of all sizes. (Drawing by Christopher E. Oesch. Adapted from Ritter et al. 2002).

through the concrete channel when natural micro-topography slows the water below transportation rate. With the stream unable to drop suspended particles continuously throughout the channel, more will deposit downstream. The accelerated flow discharging from the concrete channel will slow, changing from a laminar dominated flow regime to a turbulent flow regime causing the suspended particles to settle out an abnormally large amount on the first downstream section of topographical features (Nakamura et al. 1997). This silt and organic matter can cover aquatic animal habitat, completely destroying it. Holes, in rocks, logs or other hiding places can become filled with silt rendering them uninhabitable for aquatic life (Gregory 2002, Nakamura et al. 1997). Simplified flow regimes due to channelization is globally one of the main factors causing habitat loss and effecting biodiversity of stream ecosystems (Muotka et al. 2002). It is a lack of micro-topography which causes this, as there are no irregularities to trap sediment and nutrient rich organic matter (Muotka et al. 2002).
The introduction of micro-topography to the Rose Creek Channel will facilitate a turbulent flow regime within the concrete channel, allowing eddies and pools to form. This will create deposits of sediment and organic matter adjacent to micro-topographical features (see figure 3.1).

The author has observed sediment deposition occurring within the hardscape channel where the few micro-topographic features exist. These features are crack or joints in the concrete and corners along the fin walls of the bend. Addition of similarly functioning micro-topography to the channel will enhance this process.

**Net slowing of downstream velocity.**

With no objects or irregularities to create drag and turbulence within the hardscape channel, stream velocities increase, especially during a high volume stormflow. This increased velocity creates a “flushing” or removal of any sediment, organic matter, plants or animals which might have established themselves during moderate or low flow periods (Cook et al. 1999, Nakamura et al. 1997). This prevents any long-term establishment of riparian and aquatic flora or fauna within the channel, further segmenting habitat linearly along Rose Creek. The addition of varied topography to the concrete channel will create pools, eddies, structural shelters, and other habitat resistant to peak stormflow velocities. In addition, these added features will slow the overall velocity of the stormflow, thereby decreasing the energy with which to do damage to fragile aquatic habitat (Ritter et al. 2002, Brooks et al. 1997).

With more varied topography present within the hardscape channel, sediment and organic matter deposition will increase, which in turn will provide opportunity for plants
to grow. The author has observed an Arroyo Willow (*Salix lasiolepis Benth.*) currently growing from a sediment deposit along one of the fin walls in the elbow bend of the channel. The willow is approximately 4 years old, indicating that it has been able to withstand annual high flows. The author has also observed cattails (*Typha latifolia L.*) growing in silt deposits near the willow which have established themselves. A variety of native and non-native grasses are also currently present, growing from sediment deposits in the elbow bend of the channel. Roots from plants growing in sediment deposits will help provide structural integrity to the deposits, helping to keep them intact during high flows. Topographic additions to the hardscape channel will mimic those which have been observed to encourage sediment deposition and turbulent flow.

**Water quality.**

It has been shown that removal of streamside vegetation can increase water temperature. Removal of shade providing trees and plants allows more direct sunlight to fall on the water surface, thereby raising the water temperature (Brooks et al. 1997). Potential change in daily water temperature increase due to streamside vegetation removal can be estimated using the following:

\[ T = \frac{A R_n}{Q} \times 0.000267 \]

Where:

- \( T \) = Maximum potential daily temp. change due to solar radiation exposure in degrees F
- \( A \) = Surface area of stream newly exposed to solar radiation in feet squared.
- \( Q \) = Streamflow discharge in cubic feet per second (cfs)
- \( R_n \) = Net solar radiation received by newly exposed water surface (Btu/ft^2/minute)
Total removal of streamside vegetative cover has been reported to cause increases in temperature of up to 15 degrees C (Brooks et al. 1997). With increased temperatures, biochemical oxygen demand (BOD) increases. This means that as the water warms, algae and microbial organisms multiply faster, consuming more dissolved oxygen (DO) (Brooks et al. 1997). This lowers the amount of DO available for fish and other aquatic animals. To compound this effect, as water temperature increases, its potential to store DO decreases. This inverse relationship can be shown by the following:

\[ Os = 14.652 - 0.41022T + 0.0079910T^2 - 0.000077774T^3 \]

Where:

- \( Os \) = Solubility of oxygen (mg/l)
- \( T \) = Temperature of water in degrees C

The amount of DO can fluctuate greatly within a given time and space, which can have catastrophic effects on aquatic organisms within the body of water (Brooks et al. 1997). To reduce these effects, shade creating structures, as well as vegetative cover will be introduced into the hardscape channel which at present, fully exposes Rose Creek to solar radiation (see section 4.3).

3.2 Improve Riparian and Stream Habitat

Habitats present in Rose Creek.

Habitats found adjacent upstream and downstream of the Rose Creek hardscape channel are defined according to the Rose Creek Canyon Enhancement Plan put forth by KTUA, Merkel & Associates, Inc. Nasland Engineering, June 2000.
These areas are: Riparian Woodland, Southern Willow Scrub, Mule Fat Scrub, Coastal and Valley Freshwater Marsh, and Exotic Plantings. The establishment of plants and trees in the channel will create habitat for a variety of birds and animals.

**Riparian Woodland**

These areas are primarily non-willow trees, which require more water than willow and other marsh species of plants and trees. These include Western sycamore (*Platanus racemosa*) and Freemont Cottonwood (*Populus fremontii*). Trees in these areas are generally taller, and form a denser canopy than that of the Southern Willow Scrub. With a more extensive canopy architecture, this area provides habitat to raptors and other bird species native to Riparian Woodlands (Merkel & Assoc. et al. 2000).

**Southern Willow Scrub**

This area is home to Willows (*Salix lasiolepis, S. lucida ssp. Lasiandra*). These trees tend to grow single or in small groves. A canopy is only formed in the groves, leaving the rest of the area open. Vegetation of the understory is of Marsh habitat. The canopy formed within the groves is home to various songbirds (Merkel & Assoc. et al. 2000).

**Mule Fat Scrub**

Mule Fat (*Baccharis salicifolia*) is a bushy tree that grows in full sun and tolerates adverse soil conditions. It grows in thick stands. Other plants found in this habitat area are; Celery (*Apium graveolens*), Bermuda Grass (*Cynodon dactylon*), English Plantain (*Plantago major*), and Western Ragweed (*Ambrosia psilostachya*) (Merkel & Assoc. et al. 2000).
**Marsh Land**

Types of marsh found adjacent to the channel can be defined as Coastal-Valley Freshwater Marsh. Common to these areas are stands of Broad-leaved Cattail (*Typha latifolia*), various species of Bulrush (*Scripus spp.*), and a variety of grasses, both native and non-native. This is a low-lying area and is covered with water during and after measurable rains. During non-rainy periods this habitat is for the most part muddy with occasional shallow pools of standing water (Merkel & Assoc. et al. 2000).

**Open Water Channel**

Areas of Open Water Channel are where the deepest, most consistent flow of water occurs. In this region of Rose Creek, this channel is bare mud, occasionally lined with a variety of grasses, both native and non-native. Water does not flow continually during normal to non-rainy periods. During these times this area consists of pools segregated by slightly higher topography. During periods of rain the entire mud channel is covered with flowing water (Merkel & Assoc. et al. 2000).

**Exotic Plantings**

This includes species not native to the area that were either planted, or escaped cultivation. Non-natives commonly found in this area are; Brazilian and Peruvian Peppertree (*Scloporus occidentalis*), Eucalyptus (*Eucalyptus sp.*), Canary Island Date Palm (*Phoenix canariensis Chaub*), Fan Palm (*Washingtonia robusta Wendle*), Pampas Grass (*Cortaderia jubata*), Mojave Yucca (*Yucca schidigera Roezl ex Ortgies*), and large planting of Iceplant (*Mesembryanthemum sp.*). The Iceplant is located mainly along the
edges of the Rose Creek riparian zone, bordering roads and parking lots (Merkel & Assoc. et al. 2000).

**Floral improvements.**

When implementing floral improvements, consideration to Rose Creek’s fluvial processes must be taken into account. Research indicates a close dependence on natural fluvial hydrologic characteristics and processes by indigenous plant species. These natural flow features can be characterized by; magnitude, frequency, duration, timing, and rate of discharge (Fuller et al. 1992, Hupp et al. 1996, White et al. 2002). These plants naturally establish themselves in locations in and around the stream channel where the variation in flows throughout the year facilitates suitable amounts of water for germination, seed dispersal, seed transport, and redeposition in downstream locations suitable for further establishment (Mauchamp et al. 1999, White et al. 2002). When these variations in flow are altered through channelization and removal of micro-topographic features, plant communities are drastically effected (Fuller et al. 1992, Hupp et al. 1996, White et al. 2002).

With only seasonal continuous surface flow, and inaccessible groundwater due to the hardscape channel bottom, the trees of a Riparian zone would not have access to the amount of water needed to survive (Wang et al. 2001). It is not practical or necessarily desired to create all of the Rose Creek habitats within the hardscaped channel section. From species already present within the channel, growing from small sediment deposits, it is realistic to promote Southern Willow Scrub, Coastal-Valley Freshwater Marsh, and Open Water Channel habitat. Plant species of these habitats would be best suited for
hardscape channel growth. Riparian woodland would not be feasible due to high groundwater demand.

**Faunal habitat improvements.**

Just as floral habitats are effected by changes in flow patterns brought on by urban channelization, so are the animal communities associated with them (White et al. 2002, Muotka et al. 2002). As stated above, Willow Scrub, Marsh, and Open (fresh) Water Channel habitats are the most practical and naturally suited for the hardscape channel area. They support a variety of animals. Animal species found in these habitats along Rose Creek have been documented by Merkel & Associates in their June 2000 report and are found listed in Appendix A.

The author has observed Mallards, Egrets and Herons making use of open water and marsh habitat at the downstream end of the hardscape channel and in the channel following rainy periods when there is flowing water in the channel itself. This indicates that if marsh and open water habitat were continually present, these species could incorporate the modified hardscape channel area into their year round habitat. It is realistic that all of the native species listed in appendix A would be able to make use of the hardscape channel area if their habitat was expressed there. Not only will this expand their habitats to the hardscape channel area itself, but will serve as a pathway to up or downstream habitats beyond, thereby linking the Rose Creek natural corridor. As these plant and animal species have already experienced a considerable spatial strain from encroaching urbanization, any additional connectivity and expansion of the habitats will

3.3 Meeting Human/Urban Needs

Flood safety.

Within an urban setting, a goal of any stream channel modification is the safety of nearby inhabitants and urban structures. The Rose Creek Hardscape channel was designed and built with the intention of passing peak stormflow of the Miramar Hydrologic Unit quickly to Mission Bay and preventing flooding beyond a bank-full volume. It does in fact do this. However, the hardscape channel’s volume is far larger than is needed to safely pass a 50-year precipitation (Ppt.) event. All “enhancement” materials introduced into the hardscape channel are designed to retain an ample margin of safety in a peak stormflow event (See section 4.1 for design parameters). The aim of the Rose Creek Hardscape Naturalization Project is to continue to meet human and urban safety needs, with the additional goal of alleviating urban development stress of the already marginalized river ecosystem of Rose Creek.
4.0 PROJECT DESIGN

4.1 Parameters Used for Design Engineering

When designing in-channel modifications, it is crucial that the additions will not promote flooding above the channel. The following will illustrate mathematically that the channel modifications suggested by this paper will not cause additional flooding based on a 50 year precipitation event. A 50 year precipitation event is used for this calculation, as it would produce a significant amount of stormflow through the channel. It has a relatively infrequent return interval, and will provide a margin of safety in the calculation results.

Miramar Hydrologic Unit 906.4 drains a total of 27,677 acres (120,561,012 square feet) which will pass through the channel on its way to Mission Bay, and the ocean beyond (La Rosa 2002, Project Clean Water 2003).

A 50 year precipitation (Ppt.) event for coastal San Diego, CA is 3.5 inches (0.29 feet) within a 24 hour period. This equates to 0.012 feet of Ppt. per hour (NOAA 2003). The Rational Method of watershed runoff will be used to calculate the discharge volume in cubic feet discharged per second (cfs) from the Rose Creek concrete channel.

\[ Q = CIA \]

\[ Q = \text{Peak Stormflow (cfs)} \]
\[ C = \text{Runoff Coefficient} \]
\[ I = \text{Ppt. Intensity in feet per hour} \]
\[ A = \text{Area of watershed in square feet} \]
The runoff coefficient is a number value ranging between 0 and 1.0. It reflects the runoff efficiency of the watershed. For example, a watershed where a large amount of precipitation is stored in the soil or taken up in vegetation will have a low runoff coefficient. Whereas a watershed with less permeable soils, and or less vegetation would have a coefficient closer to 1.0. For comparison, undisturbed woodland with a high soil porosity could have a C value around 0.10. Cultivated heavy soils or clays could have a C value around 0.50 (Brooks et al. 1997). For the application of this method to the Miramar Hydrologic Unit, we will use a C value of 1.0. This would indicate that no precipitation is being retained in the watershed, or lost to evapotranspiration. The reason for assuming zero loss of runoff to watershed storage is because of the high degree of urbanization in the watershed that has and is taking place. Paved surfaces do not allow water to infiltrate the soil. Water that falls on these surfaces will be quickly transported into storm drains, and down slopes into the waterway. In a report published by Michael D. White, Ph.D., and Keith A. Greer, M.A., of the Conservation Biology Institute, runoff amounts have been steadily increasing from the larger Los Penasquitos watershed. A regression analysis of discharges from 1972 to 2002 shows an annual runoff increase of 4%. During this time period, urbanization of the watershed rose from 9% to 37%. There was no significant trend in precipitation during this time period.

In addition, the soil and vegetative cover found in the watershed tend to be of lower permeability (Brooks et al. 1997). Sage Brush and Chaparral have high levels of long chained hydrocarbons. When these plants drop loose or dead plant mater onto the soil, these hydrocarbons can bond to the soil in the A Horizon (top layer of soil) creating
a hydrophobic layer of soil. This effect is enhanced by hot sun or wildfires further bonding the long chain hydrocarbons into the A Horizon, thereby lowering the soil permeability even more (Brooks et al. 1997). Using a C value of 1.0 will give a safer margin, providing the result with a higher peak stormflow runoff volume.

Our equation values are then:

\[ Q = Q \]
\[ C = 1.0 \]
\[ I = 0.012 \text{ feet Ppt. per hour} \]
\[ A = 120,561,012 \text{ square feet} \]

\[ Q = (1.0) (0.012) (120,561,012) \]
\[ Q = 1,446,732 \text{ cubic feet of runoff per hour} \]

To find cubic feet of stormflow per second, 1,446,732 cubic feet per hour will be divided by 60 (60 minutes per hour): 1,446,732 cubic feet per hour/ 60 minutes = 24,112 cubic feet per minute. Then again divided by 60 (60 seconds per minute) to find the cubic feet per second of discharge volume (cfs): 24,112 cubic feet per minute/ 60 seconds = 402 cfs.

Next, the equation \( Q = VA \) will be used to help determine the velocity of the water in relation to the height of the water while passing through the concrete channel area (LMNO Eng. 2003).

\[ Q = VA \]
\[ Q = \text{stormflow (402 cfs)} \]
\[ V = \text{velocity in feet per second} \]
\[ A = \text{area of channel cross section in square feet (width* depth)} \]

The width of the Rose Creek hardscape channel is 100 feet. Therefore, if the stormflow were moving the volume of 402 cfs at only 1 foot per second (fs), the height of the water
a hydrophobic layer of soil. This effect is enhanced by hot sun or wildfires further bonding the long chain hydrocarbons into the A Horizon, thereby lowering the soil permeability even more (Brooks et al. 1997). Using a C value of 1.0 will give a safer margin, providing the result with a higher peak stormflow runoff volume.

Our equation values are then:

\[ Q = Q \]
\[ C = 1.0 \]
\[ I = 0.012 \text{ feet Ppt. per hour} \]
\[ A = 120,561,012 \text{ square feet} \]

\[ Q = (1.0) \times (0.012) \times (120,561,012) \]
\[ Q = 1,446,732 \text{ cubic feet of runoff per hour} \]

To find cubic feet of stormflow per second, 1,446,732 cubic feet per hour will be divided by 60 (60 minutes per hour): 1,446,732 cubic feet per hour \div 60 \text{ minutes} = 24,112 cubic feet per minute. Then again divided by 60 (60 seconds per minute) to find the cubic feet per second of discharge volume (cfs): 24,112 cubic feet per minute \div 60 \text{ seconds} = 402 \text{ cfs.}

Next, the equation \( Q = VA \) will be used to help determine the velocity of the water in relation to the height of the water while passing through the concrete channel area (LMNO Eng. 2003).

\[ Q = VA \]

\[ Q = \text{stormflow (402 cfs)} \]
\[ V = \text{velocity in feet per second} \]
\[ A = \text{area of channel cross section in square feet (width* depth)} \]

The width of the Rose Creek hardscape channel is 100 feet. Therefore, if the stormflow were moving the volume of 402 cfs at only 1 foot per second (fs), the height of the water
in the channel would be 4.02 feet. If the water were to speed up to 2 feet per second, then the water height would lower to 2.01 feet, etc. Due to the smooth and currently unobstructed bottom surface, and straight path of the channel, it is more likely that the stormflow volume moves at a rate higher than 1 fs, thereby having a lower depth than 4.02 feet.

For comparative study of discharge surface velocities, the author recorded a stormflow event on the South Fork of Little River at Moonstone Beach, California. In this study, 3-4 fs of discharge were recorded. This was on a straight stretch of river with similar slope and relatively smooth sand bottom topography. The hardscape channel of Rose Creek would have an even smoother surface than the sand, with its cement bottom. Given this measurement, it is more likely that peak stormflow of a 50 year Ppt. event in the Rose Creek Hardscape Channel would be passing closer to the 3-4 fs velocity thereby lowering the water height to between 1.005 to 1.34 feet deep within the channel. The height of the cement wall is around 14 feet, putting this volume of stormflow clearly below the top of the walls.

When calculating storm flow, the base flow of the stream must be factored into the equation, and the stormflow is a volume added to that amount. However, at this point in time, there is very little constant natural year-round baseflow moving though the Hardscape channel in Rose Creek (White et al. 2002). A trace amount of wetness can be detected on the hardscaped channel bottom in all but the driest months. There is a supplemented urban runoff baseflow, and a small amount of standing water is usually present in the non-channeled streambed above and below the channel. When what little
baseflow moving through Rose Creek gets to the channel, it spreads out across the flat, 100-foot wide channel, reducing it to a sheet trickle. With this decreased depth, and increased width, the water surface is greatly increased. This increased surface area creates accelerated evaporation. This evaporation is also aided by solar warming of the cement channel bottom. With low relative air humidity, solar warming and a widened and shallowed flow, the baseflow quickly dries up entirely within the first 100 feet inside the channel, thus reducing the baseflow in the channel effectively to 0 cfs. Therefor, with an effective baseflow of 0 cfs though the channel, the total peak stormflow volume of 402 cfs remains unchanged.

4.2 Specifications Based on Parameters

The total channel holds a maximum volume of approximately 700,000 cubic feet (100 feet wide, 700 feet long, and using a safe height of 10 feet high). The slowest velocity (1fs) of a 50 year Ppt. event would yield a volume of water in the channel of 281,400 cubic feet. This is a safety margin of 418,600 cubic feet.

Total additions to the hardscape channel should not exceed 15,000 cubic feet. From preliminary channel plot designs, a volume of 15,000 cubic feet is ample. If the volume of 15,000 cubic feet were laid out flat in the channel bottom, it would constitute an aggradation of only about 3 inches. This would allow for about 55,000 cubic feet of plant and soil matter to accumulate before the total equivalent aggradation would reach 1 foot. The additional materials in the channel will slow the overall velocity as well as displace water. Even with an addition of 70,000 cubic feet of total additional mass to the channel (accounting for a 1 foot aggradation), and figuring a velocity slowing to that of
.75 ft, the water height would reach 7.03 feet high on the channel wall. This leaves a safety margin of over 6 feet. As stated earlier, the storm flow would realistically be more around 3-4 ft, slowing to 1-2 ft with the additions to the channel including plant growth and sediment deposition, however .75 ft was used in this calculation to provide a larger margin of safety. Plants and sediment would need to be monitored over time to make sure that safety margins are maintained (see section 5.3).

4.3 Key Structure Designs

High/ Low Flow X Channel.

Due to the climate of San Diego, Rose Creek experiences extremes in its flow; extremely low flow during moderate to dry periods, and fast peak-flows during storm events characteristic of urbanized Southern California. The difficulty of a hardscape channel modification in this region is meeting the requirements of both extreme flows. In a region with a more regular annual Ppt. pattern and with more constant flow levels, structures could be designed for a smaller variance in flow, and duel functioning high and low flow structures would not be as important.

During times of low flow, plant and animal communities develop themselves in proximity to the continually present water of low flow conditions. These generally are the lowest points of the streambed. During peak storm-flows, these areas are covered with fast moving water, many times disrupting and destroying niche habitat of plants and animals established during low flows. With the absence of micro and macro topography within the hardscape channel, this purging effect is very pronounced (Nakamura et al. 1997).
Figure 4.0 High/low flow X channel cross section looking upstream. (Drawing by Christopher E. Oesch).

The High/ Low Flow X Channel will help to alleviate this stress. This design features a 6 inch high raised and contoured berm which will funnel low flow towards the west (more shaded) side of the channel. It will narrow the width available to the low flow, thereby increasing the depth. Positioning the low flow closer to a shaded wall will assist in reducing water temperatures. This low flow channel will meander along the shade wall, incorporating various micro-topographical features and pools. This design will better mimic the varied flow and habitat of a natural stream. To protect habitat which will establish itself in this low flow enhanced area, a high flow deflection berm will run perpendicular to the angled low flow funnel (see figure 4.2). This contoured berm will be approximately two feet high. It features an opening along the bottom where
the low flow passes through on its path to the low flow habitat area (see figure 4.0 and 4.1). This will allow low flow to pass through the opening, yet limit the amount. Peak storm flows will be deflected by the high flow berm, and focused off to the right. This will take a great deal of stress from high velocity stream flow off of the low flow habitat area. It is likely that the low flow habitat area will be inundated and covered by water, however the flow velocity will be greatly reduced. Even during times of extreme high flow where the water covers the top of the high flow deflector berm, it will still provide protection.

In a non-hardscape channel application, using berms (or groynes) to alter flow direction requires the use of bank armor (rock or logs) to where the flow is directed in order to protect the bank from accelerated erosion. However, for a hardscape application, this is not relevant since erosion is not an issue within the channel. This is one factor which differs greatly from non-hardscape channel restoration practices.

These berms can be constructed with cement and gravel mix, reinforced with traditional rebar. For more finely contoured areas, where rebar may be to big or unnecessary, hog wire, or even chicken wire are suitable reinforcement materials. Prior to construction of the berms, holes would be drilled into the hardscape channel bottom, in which rebar would be anchored into. To finish the surface, a variety of materials could be used, depending on the desired aesthetic. River smoothed cobble stones could be an suitable option. These could be attached with mortar, or other hydraulic cement with strong bonding characteristics. Conceptually, these berms would mimic bedrock. They are meant to be permanent contours, and to withstand high velocity stormflows. This
would include impacts from upland materials being washed along in the stormflow, items such as small to medium sized rocks, small logs and other organic debris, and man made items such as shopping carts, tires, and various plastic materials.

Figure 4.1 High/low flow X channel cross section looking upstream. Note the low flow passageway through the 2ft. tall high-flow deflection berm. (Drawing by Christopher E. Oesch).
Figure 4.2 High/low flow X channel top view. (Drawing by Christopher E. Oesch).
**Shade F Structure.**

The Shade F Structure is a concept adapted from an underwater overhead environment structure designed by the River Engineering Branch of the province of Alberta Canada, Environmental Department to improve fish habitat (Lowe 1996). The Shade F Structure in the application of Rose Creek, will most likely provide habitat for amphibians, lizards, crayfish and some types of birds. It has both a component of underwater overhead habitat for low flows, as well as dry land shaded overhead environment in close proximity to water. The top overhead shade structure will feature a soil box where plants can be grown (see figures 4.3 and 4.4).

This structure would be built along the wall of the hardscape channel where the low flow berms channel the water directly along the wall. The F Structure can be put in place to create shaded and cooler aquatic and adjacent protected dry land habitat. The upstream and downstream edges of the structure are at 45 degrees to reduce the structural stress from high velocity storm flows. In addition, the 45 degree downstream end, will assist in reducing potentially destructive turbulence to protect habitat above or under the “shelves” of the F Structure. This structure is for providing shade habitat, and is not for creating turbulent flow, or encouraging sediment deposition. Therefore, it has a more streamlined, hydrodynamic design.

As the soil box on the top of the structure is a confined area, not in proximity to constant groundwater, the plants selected for the application would need to be ones which require little water. Also, they would need to be able to survive with limited rooting space. Suitable candidates for this would be native cacti, yucca, or other succulents.
The F Structure would be form poured cement, reinforced with rebar and or hog wire depending on the size and shape of the specific structure. Holes would be drilled into the hardscape channel walls and bottom in which rebar would be used to anchor the structure. F Structures could be made in variety of sizes and proportional variations. They could be finished with cobblestones for a more natural appearance.

Figure 4.3 F Structure shade provider. Lower level provides underwater overhead environment during low-flows. Top of lower level provides shaded dry habitat. Top level provides extended shade over low-flow pool, and includes a soil box to house plants. (Drawing by Christopher E. Oesch).
Figure 4.4 Top view of F Structure. Note: soil box for plants and 45 degree tapered leading and trailing edges. (Drawing by Christopher E. Oesch).
**Sediment Trap Deltoid.**

The Sediment Trap Deltoid is a basic topographic addition to the streambed. It is simply a modified deltoidal shape with 15 degree in swept angles on its downstream side (see figure 4.6). This design is meant to trap sediment by creating turbulent flow around the corners of its downstream ends, slowing the water below transportation rate for sediment and organic particles, and allowing them to settle out of suspension. This will create sediment and organic matter deposition behind the deltoid. It is predicted that this deposition in time, will be able to sustain plant growth. The deltoid itself will continue to protect emergent plant communities from high velocity storm flows.

The deltoidal shape was selected for this application over other shapes, because the goal of an in-hardscape channel naturalization project is twofold; to create habitat and to do so without causing flooding above the channel walls. The deltoid can create turbulent drag in a strategic location, while the streamlined hydrodynamic upstream end will pass storm flow more efficiently.

These deltoids can be made in all sizes, from 2 inches high, to 24 inches high. A series of 3-inch high deltoids clustered in a field could create a rough section of channel bottom micro-topography. A 2-foot high deltoid could be used to create a large sediment deposit suitable to grow cattails or willow.

The deltoids are constructed out of poured cement, supported by a rebar, hog wire or chicken wire reinforcement system depending on scale. They are anchored to the cement by rebar drilled into the hardscape channel bottom.
Figure 4.5 Top, side and end views of the Sediment Trap Deltoid. (Drawing by Christopher E. Oesch).
5.0 MATERIALS AND CONSTRUCTION

5.1 Materials

The main contours and structures added to the channel bottom and walls will be constructed out of a mix of portland cement and gravel. They will need to be reinforced with steel, and can be textured with smooth river cobblestones. The cobblestones can be attached with a mortar. All structures and their finished surfaces will need to remain intact under water, during high velocity flows and the stresses that accompany such a situation. Insufficient durability is cited as a leading cause of channel modification failure (Brown 2001, Lowe 1992, Morris et al. 1999, Olson et al. 1989

Materials list.

Portland Cement (sand, gravel, water for mixing)

Steel rebar, hog wire and chicken wire

Fast drying hydraulic cement (for anchoring rebar into channel bottom and sides)

Mortar (for attaching finished surface cobblestones)

Smooth River cobblestones (for finished surfaces)

Soil (for soil boxes on the tops of F structures)

Plants and seeds (if it is desired to introduce plants by human input versus waiting for it to happen naturally over time).

5.2 Construction

Some of the structures, such as the F structure and the deltoid, could be form poured. For the berms and other “organic” shaped contours, a good deal of work by hand

45
is recommended. To help create shapes and contours for the berms, a “skeleton” of chicken wire and hog wire can be used to sculpt the general shape of the berm. In addition to helping provide shape, it increases structural integrity. Once the shapes are dry, finish texture may be applied (such as mortar and cobblestones). Channel modifications will need to be checked regularly to make sure finished surfaces are staying intact, as well as basic structural integrity.

5.3 Maintenance

Once constructed, maintenance is crucial. Urbanization has been shown to increase peak storm-flow discharges, especially those with lower return intervals (White et al. 2002). The initial permanent additions will add an additional volume amount. As sediment accumulates, and as trees and plants grow, this volume in the channel will increase over time. Not only will additional volume to the channel increase the water level during a peak stormflow event, but the organic shapes will also create drag, reducing the water velocity, thereby further raising the water height in the channel. This volume of input to the channel will need to be monitored so that it does not exceed a safe margin. General trash removal and upkeep of an aesthetically pleasing area should occur.
6.0 CONCLUSIONS/ SUGGESTIONS FOR FURTHER RESEARCH

6.1 Summary

Process.

Fluvial processes are dynamic ones (Sovern 2000). The tension of force and resistance is constantly changing and modifying the stream channel over time. Water pushes against rock and earth, eroding or changing course of the stream. Sediment is suspended and deposited in different locations, aggrading and degrading a streambed. It is this continual process of change that helps to create a natural and well functioning waterway (Sovern 2000).

To the goals of urbanization, this process of change is not desirable. Clearer definition of stream channels and paths allow for development right up to the edge of a permanent channel. With an unchanneled, widely meandering and unpredictable stream path, developers must allow a wider buffer zone. Rose Creek, as well as many other urban watersheds have already been defined to a non-meandering channel. This has occurred by placement of rock riprap, concrete walls, pipe systems, and hardscaped channels.

Effects.

At this point in history, many times it is unrealistic to return the streams to their pre-
urbanization paths, however steps may be taken within the context of current
development to enhance the habitat of indigenous plant and animal populations. A more
“natural” functioning hydrology of an urban stream may be created, while working
within existing confines.

**Safety.**

One fundamental difference between adding flow altering structures to a
hardscape channel versus that of a natural channel is erosivity. When redirecting flow
towards a channel bank, it is of extreme importance to sufficiently protect against
erosion. If this does not happen, the newly focused flow will erode the bank at an
accelerated rate. In a hardscape channel, the concrete wall will not erode as soil does, so
this is not a factor when determining new flow patterns. However, if a major peak-flow
current is being directed towards a hardscape channel wall, considerations are for the
structural integrity of the wall, as well as the promotion of flooding at that location.

While attempting to create slower, more turbulent flow within hardscaped
channels, volume of added structures is key. Structures should be designed to perform
their desired function, with the lowest volume and drag, as to not disrupt existing flood
safety margins. Continual monitoring for volume of added materials to the channel is
essential to prevent flooding, especially over time as urbanization within the watershed
continues to grow, thereby increasing peak runoff volumes.
Theory and practice.

There are many special interest groups involved with restoration of urban watersheds. Some are bird or fish biologists. Some are native plant species botanists. Some are water quality specialists. The list of specific interests goes on. Most all of their interests would be assisted by general overall improvements to the hydrologic function of a channelized stream. However, after a certain point, views may differ as to what the “important” habitat or species is that should be focused on, many times at the marginalization of others. Common examples of this are stream restoration by sport fishing groups for the promotion of one species of fish. Or wetland restoration by bird watchers, promoting only the restoration of bird habitat.

Stream ecosystems are complex and interdependent ones, where the marginalization or extinction of one species, can have far reaching and unexpected effects. It is to the benefit of all species to promote improvement of the whole system, not just creation of habitat for one species.

This process must be gone about in a careful way, as many of these urban stream systems have been in decline and marginalized for so long that their native inhabitants have experienced sub-healthy conditions for so long, that improvement to the habitat will be a big change. A change which will require time for adjustment by native species.

Restoration.

It is both impractical to promote the return of Rose Creek to its “original” path, as it is impractical to deconstruct the hardscape channel within its present location.
However, it is practical to create a functioning naturalized habitat within the existing channel. This approach has two advantages over removing the hardscaped channel.

First, urban channels have been put in place to perform certain functions, and the process needed to gain permission to have them removed would be unproductive (La Rosa 2002). Second, there would be significant deconstruction cost for the removal of the concrete, and the following “habitat enhancement”. For many non-profit, or community based organizations with limited funds, this may put projects which include hardscape channel removal financially out of reach (Ellis 1995, Savard et al. 2000).

Obviously an in-hardscape channel naturalized environment would not be as natural as an entirely undisturbed stream channel, however one must balance urban need, cost, legal regulations and current levels of habitat degradation (Ellis 1995, Savard et al. 2000). In its entirety, hardscape channel naturalization meets many of these needs, making it an attractive option for habitat enhancement for urban watercourses effected by hardscape channels. When dealing with urban watershed restoration efforts, it is necessary to realize capacities and potentials, keeping in mind that the systems have been fundamentally altered. Failure to keep this perspective can lead to unrealistic expectations of the stream ecosystem (Ebersole et al. 1997, Ellis 1995).

**Future study.**

The Rose Creek hardscape channel naturalization project will provide an easily accessible location for study and monitoring to occur. Examples for study and evaluation could include:
Improvements to floral community

Document plant species present in hardscape channel before, and at various time periods after naturalization, including abundance, habitat complexity and health.

Improvements to faunal community

Document animal species residing in the hardscape channel before, and at various time periods after naturalization, including abundance, health, and interaction with other species populations.

Water quality

Sample water quality before and at various time periods after naturalization. Document changes in pollutants including heavy metals, coliforms, and other urban waste, as well as nutrient, oxygen and turbidity levels.

Sediment depositional patterns

Sediment deposition and downstream aquatic life health related factors could be recorded before and at various time periods after naturalization. Sediment amounts in channel, and discharges into Mission Bay could also be monitored and compared.

Hydrologic function

Morphologic and fluvial processes within the channel could be compared before and at various time periods after naturalization.

Changes in peakflow runoff patterns

Peak stormflow discharges could be monitored and compared to help indicate design improvements in hardscape naturalization which could help pass water more efficiently yet, be effective in creating desired habitat and fluvial effects.
These are but a few potential ideas for study resulting from the implementation of this project. With coastal water quality very poor (La Rosa 2002, Project Clean Water 2003), and urbanization in San Diego County continually growing, there is a need and a place for this project.

6.2 Concluding Remarks

The Rose Creek Harscape Channel Naturalization Project takes a rather active management approach to enhancing the system. This may be criticized by Deep Ecologists who's philosophy espouses a more passive role, less dependant on building and engineering. A method which would rely more on simply letting nature take its course and trying to prevent any more inputs to they system.

It is the feeling of the author that urbanized watersheds, such as Rose Creek, have been so fundamentally altered, in morphology, baseflow supply, flow patterns, storage capacity, plant and animal habitat, spatially, and pollution amounts, that active management is needed to swing the pendulum back the other direction. It is not as though these urban stream systems would remain untouched if environmental engineers would just stand back and watch. These watersheds are constantly undergoing further urbanization and habitat marginalization from other influences which do not take the health of the local ecosystem into consideration (Leitao et al. 2002).

Hardscape channel modification serves a role in habitat improvement for when total removal of the hardscape channel is not an option. Through experimentation, and long term testing, hardscape channel modification will progress, yielding further valuable results. Clearly the absence of channelization would better replicate natural hydrologic
processes, and this paper is not recommending in-channel modification when removal is possible. However, in its context, hardscape channel naturalization can provide valuable benefits.
REFERENCES


APPENDIX A

LIST OF ANIMALS FOUND IN ROSE CREEK HABITATS
Fishes

Common Carp (Cyprinus carpio)  Freshwater Aquatic
Green Sunfish (Lepomis cyanellus)  Freshwater Aquatic
Sailfin Molly (Poecilia latipinna)  Freshwater Aquatic
Mosquitofish (Gambusia affinis)  Freshwater Aquatic

Amphibians

Garden Slender Salamander (Batrachoseps major)  Emergent Wetland
Pacific Chorus Frog (Pseudacris regilla)  Freshwater Aquatic, Emergent Wetland

Birds

Great Blue Heron (Ardea herodias)  Freshwater Aquatic, Coastal-Valley Freshwater Marsh
Great Egret (Casmerodius albus)  Freshwater Aquatic, Coastal-Valley Freshwater Marsh
Snowy Egret (Egretta thula)  Freshwater Aquatic, Coastal-Valley Freshwater Marsh
Green Heron (Butorides virescens)  Freshwater Aquatic, Coastal-Valley Freshwater Marsh
Black-crowned Night Heron (Nycticorax nycticorax)  Freshwater Aquatic, Coastal-Valley Freshwater Marsh
Little Blue Heron (Egretta caerula)  Coastal-Valley Freshwater Marsh
Mallard and Mexican Mallard (Anas platyrhynchos)  Coastal-Valley Freshwater Marsh
Sharp-shinned Hawk (Accipiter striatus)  Southern Willow Scrub
Cooper’s Hawk (Accipiter cooperii)  Southern Willow Scrub
Red-shouldered Hawk (*Buteo lineatus*) Southern Willow Scrub

Red-tailed Hawk (*Buteo jamaicensis*) Southern Willow Scrub

Virginia Rail (*Rallus limicola*) Coastal-Valley Freshwater Marsh

Sora (*Porzana carolina*) Coastal-Valley Freshwater Marsh

Common Moorhen (*Gallinula chloropus*) Coastal-Valley Freshwater Marsh

Anna’s Hummingbird (*Calypte anna*) Southern Willow Scrub

Costa’s Hummingbird (*Calypte costae*) Southern Willow Scrub

Belted Kingfisher (*Ceryle alcyon*) Southern Willow Scrub

Northern Flicker (*Colaptes auratus*) Southern Willow Scrub

Pacific-slope Flycatcher (*Empidonax difficilis*) Southern Willow Scrub

Black Phoebe (*Sayornis nigricans*) Southern Willow Scrub

Ash-throated Flycatcher (*Myiarchus cinerascens*) Southern Willow Scrub

Western Kingbird (*Tyrannus verticalis*) Southern Willow Scrub

Western Scrub-Jay (*Aphelocoma californica*) Southern Willow Scrub

Bushtit (*Psaltriparus minimus*) Southern Willow Scrub

Bewick’s Wren (*Thryomanes bewickii*) Southern Willow Scrub

House Wren (*Troglydites aedon*) Southern Willow Scrub

Marsh Wren (*Cistothorus palustris*) Coastal-Valley Freshwater Marsh

Ruby-crowned Kinglet (*Regulus calendula*) Southern Willow Scrub

Cedar Waxwing (*Bombycilla cedrorum*) Southern Willow Scrub

Warbling Vireo (*Vireo gilvus*) Southern Willow Scrub

Orange-crowned Warbler (*Vermivora celata*) Southern Willow Scrub
Nashville Warbler (*Vermivora ruficapilla*) Southern Willow Scrub

Yellow Warbler (*Dendroica petechia*) Southern Willow Scrub

Yellow-rumped Warbler (*Dendroica coronata*) Southern Willow Scrub

Black-throated Gray Warbler (*Dendroica nigrescens*) Southern Willow Scrub

Townsend’s Warbler (*Dendroica townsendi*) Southern Willow Scrub

MacGillivray’s Warbler (*Oporornis tolmiei*) Southern Willow Scrub

Common Yellowthroat (*Geothlypis trichas*) Coastal-Valley Freshwater Marsh, Southern Willow Scrub

Wilson’s Warbler (*Wilsonia pusilla*) Southern Willow Scrub

Western Tanager (*Piranga ludoviciana*) Southern Willow Scrub

Western Tanager (*Piranga ludoviciana*) Southern Willow Scrub

Black-headed Grosbeak (*Pheucticus melanocephalus*) Southern Willow Scrub

Blue Grosbeak (*Guiraca caerulea*) Southern Willow Scrub

Lazuli Bunting (*Passerina amoena*) Southern Willow Scrub

California Towhee (*Pipilo crissalis*) Southern Willow Scrub

Song Sparrow (*Melospiza melodia*) Coastal-Valley Freshwater Marsh, Southern Willow Scrub

Lincoln’s Sparrow (*Melospiza lincolnii*) Coastal-Valley Freshwater Marsh, Southern Willow Scrub

Golden-crowned Sparrow (*Zonotrichia atricapilla*) Southern Willow Scrub

White-crowned Sparrow (*Zonotrichia leucophrys*) Southern Willow Scrub

Dark-eyed Junco (*Junco hyemalis*) Southern Willow Scrub
Red-winged Blackbird (*Agelaius phoeniceus*) Southern Willow Scrub

Brown-headed Cowbird (*Molothrus ater*) Southern Willow Scrub

Hooded Oriole (*Icterus cucullatus*) Southern Willow Scrub

Northern Oriole (*Icterus galbula*) Southern Willow Scrub

House Finch (*Carpodacus mexicanus*) Southern Willow Scrub

Pine Siskin (*Carduelis pinus*) Southern Willow Scrub

Lesser Goldfinch (*Carduelis psaltria*) Southern Willow Scrub

American Goldfinch (*Carduelis tristis*) Southern Willow Scrub

Mammals

Virginia Opossum (*Didelphis virginiana*) Southern Willow Scrub

Desert Cottontail Rabbit (*Sylvilagus audubonii*) Southern Willow Scrub

California Ground Squirrel (*Spermophilus beecheyi*) Southern Willow Scrub

House Mouse (*Mus musculus*) Coastal-Valley Freshwater Marsh, Southern Willow Scrub

Raccoon (*Procyon lotor*) Coastal-Valley Freshwater Marsh, Southern Willow Scrub

Striped Skunk (*Mephitis mephitis*) Coastal-Valley Freshwater Marsh, Southern Willow Scrub

Invertebrates

Crayfish (*Procambarus clarki*) Freshwater Aquatic

Alfalfa Butterfly (*Colias eurytheme*) Southern Willow Scrub

Salt Marsh Skipper (*Panoquina errans*) Coastal-Valley Freshwater Aquatic