Ecological Restoration of Functional Ecosystems: Learning from Stream Restoration Projects in the San Francisco Bay Area

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In addition to ecological variables, the practice of restoring ecosystems is influenced by economic, socio-cultural, aesthetic, and political dimensions related to the development, use, ownership, and management of land and water. Understanding the way ecosystems function in modified landscapes, including how specific organisms function within urban settings, is vital to the success of ecological restoration efforts. This understanding only comes through close observation and scientific study, and necessitates collaborative work between designers and scientists where ecological restoration is a stated goal.

In our view, the primary goal of most ecological restoration projects should be to **re-establish functional ecosystems** of a designated type in a manner that allows for the maturation of these systems by natural processes – after exotic weed control, planting, and possibly grading, temporary biotechnical stabilization, and irrigation. **Restored ecosystems should be capable of responding to changing environmental conditions, particularly if they are within or near urban landscapes**. In many cases, once a site or ecosystem is restored, it will likely require periodic management in order to maintain "ecosystem integrity" in response to ongoing human impacts (Clewell, Rieger & Munro 2000). Thus, although complete restoration may be our aspiration, partial restoration is typically a more realistic goal (Cairns 2006).

Integrating Science Into the Ecological Restoration and Closely Related Planning/Design Projects

Clewell and Rieger (1997, 350) discuss the scientific questions that typically challenge practitioners and note how restoration ecologists can assist in answering questions related to "project planning, soil development, genetic selection, biotic establishment, and project evaluation." Clewell and Rieger's first "solution" for building a foundation on which to implement ecological restoration programs and projects is to learn which ecological restoration practices work, which do not, "and what can be done to improve methods for new projects". With the desire to learn from past projects, several "stream restoration" project sites near San Francisco were visited on October 9, 2007 (see photos on pages 2-6), and an extensive field trip guide shared by tour leaders (refer to www.lib.berkeley.edu/WRCA/restoration/).

Part of the essential science that practitioners of ecological restoration need to be familiar with is how larger landscapes function and change in space and time (Forman 1995; Hobbs 2002). The flows of wind, water, seeds, wildlife, sediments, and other materials between ecosystems and across landscapes are of particular importance as we determine the most appropriate restoration strategies for a site. As noted in a number of the diagrams presented by Dramstad, Olson and Forman (1996), these flows and other ecosystem processes are interrelated to the bio-physical structure and patterns of a particular landscape. While patterns influence processes, flows can also strongly influence ecosystem and landscape structure. Additionally, natural and culturally-derived disturbances influence flows, structure, succession, and community assembly (White & Jentsch 2004). To effectively address ecological functions we need team members who understand the significant interactions for the ecological settings we work within.

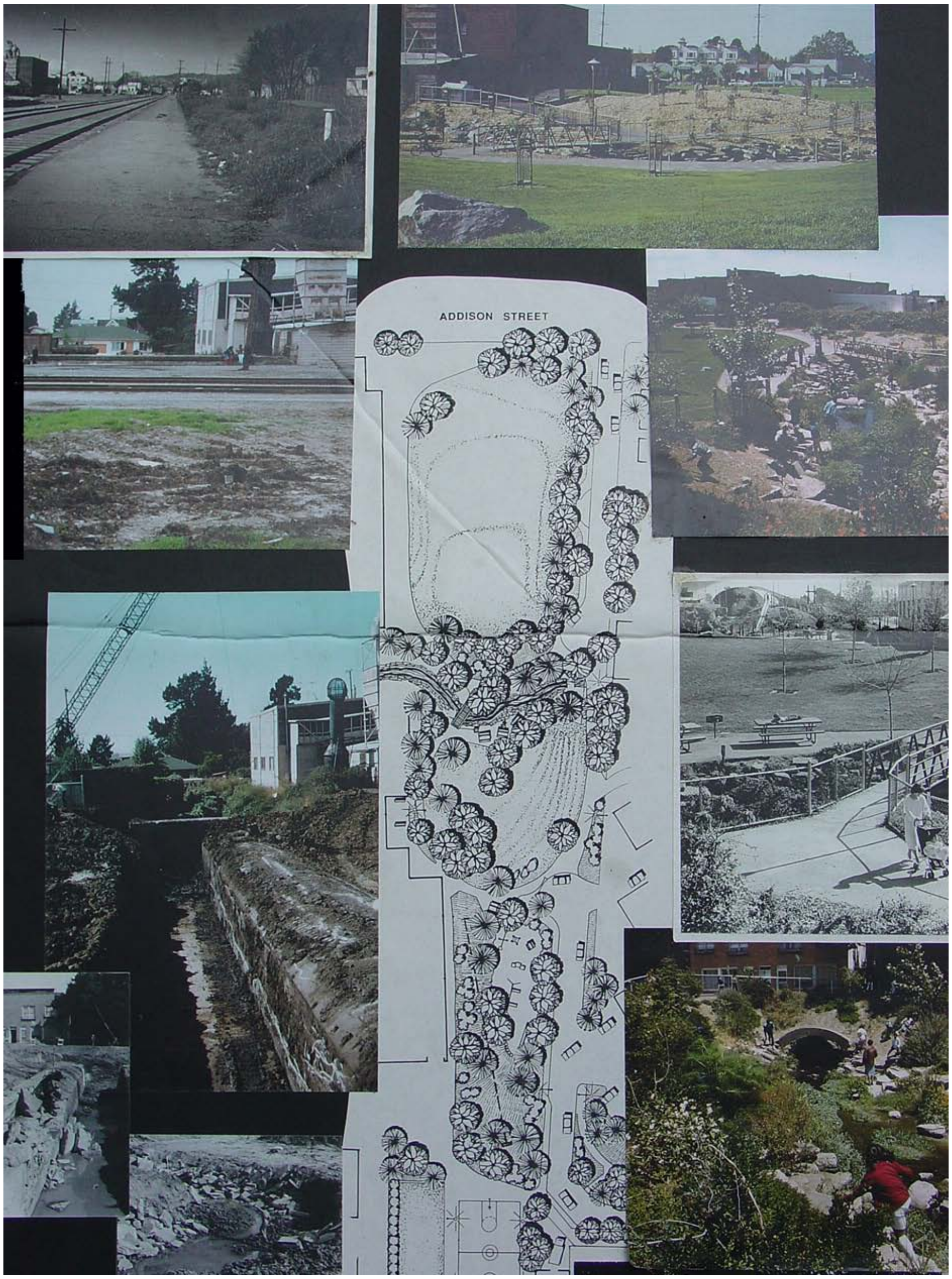
Selecting Ecological Restoration Targets in Context

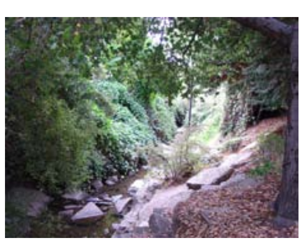
Before selecting specific ecological restoration targets we need to assess past, present, and future impacts and influences. As noted in Egan and Howell (2001, 1), "[a] fundamental aspect of ecosystem restoration is learning how to rediscover the past and bring it forward into the present – to determine what needs to be restored, why it was lost, and how best to make it live again."

Knowing what went on in the past will help us to better understand how disrupted or degraded soils, seedbanks, hydrology, biota, and other ecosystem components are, and what we will need to do to assist in their recovery. Current and projected impacts and influences must likewise be accounted for in our plans and their implementation. Otherwise our restoration efforts may be undermined in years to come.

An analysis of historical physical and ecological changes can provide the essential context within which to develop and evaluate restoration actions. A historical-geomorphological-ecological analysis can aid stream restoration in three principal ways: improving our understanding of the underlying problem (if indeed there actually is a problem), establishing realistic and ecologically/socially meaningful restoration objectives, and selecting appropriate strategies to achieve those objectives (Kondolf and Larson 1995).

Photos from Tour T15, October 9, 2007 – "Stream Restoration Case Studies in the San Francisco Bay Region", American Society of Landscape Architects ASLA Annual Meeting.





Strawberry Creek – in Berkeley, California – was one of the first day-lighted streams in the U.S. Today, the canopy has closed in and the water runs cool through this small section of open water. As in most urban areas invasive species are dominant, nevertheless important biological and aesthetic functions prevail along this reach. Broken concrete was used to stabilize streambanks.

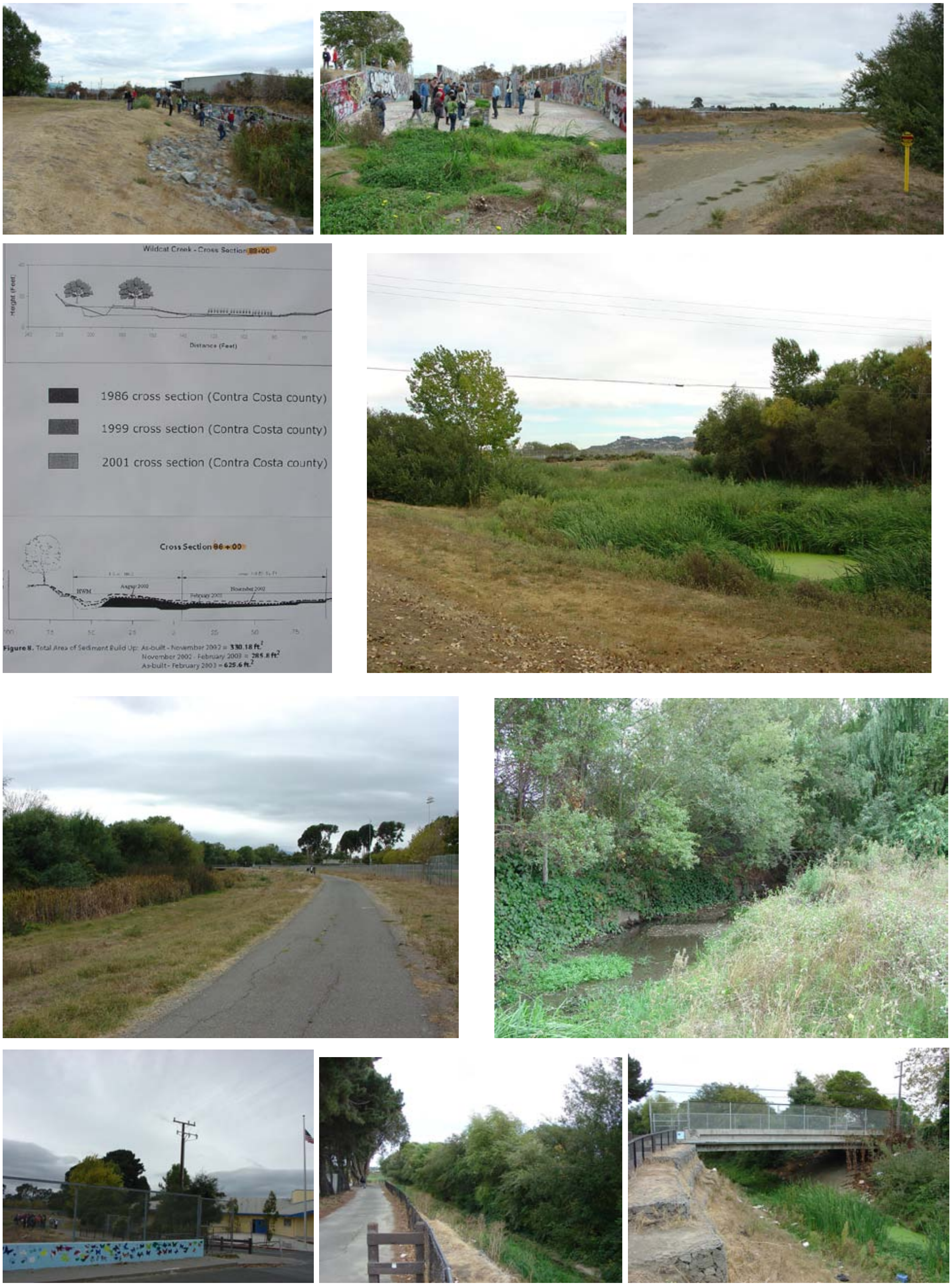
Miller Creek Reach Restoration – team members sought to restore an approximately 1-mile section of the stream as a complement to the conservation of steep hillside slopes (set aside for recreation, aesthetic enjoyment, and wildlife habitat), and construction of a new single-family residential development. Previously, the streambank along the corridor was highly-eroded.







Wildcat Creek Stabilization Work – attempted to protect an historic WPA wall at Alvarado Park using only rock and plantings. Following the "stream restoration" work a portion of the wall was undermined and broke off indicating the need for different approach to protecting the wall.



Lower Wildcat Creek Riparian Corridor Expansion – sought to increase flood capacity using a vegetated floodplain and stream corridor.

Presidio Stream Day-Lighting / Riparian Corridor Restoration.

Crissy Field Wetland and Shoreline Restoration – these ecosystems are expected to be reconnected to the Presidio Day-Lighting project site when funding allows.

Stream and Riparian Corridor Restoration
As noted in Skabelund and Kondolf (2007), stream restoration has been one of the most popular types of ecological restoration efforts nationwide, with a particularly high concentration of projects on the Pacific Coast and in the Chesapeake Bay region. To get an overview of recent trends in river restoration, the reader should consult the webpage for the National River Restoration Science Synthesis study: http://www.restoringrivers.org/. Restoring flowing rivers is particularly challenging, given that many river systems are naturally characterized by very dynamic behavior in response to high flows and fluctuations in sediment transport. Uncertainty is high for many projects. Each river restoration project should be treated as an experiment, through which we can better understand the system response and thereby improve future project performance. Unfortunately, this is rarely done. However, systematic post-project appraisals of completed restoration projects are now being undertaken in California (http://lib.berkeley.edu/WRCA/restoration/), Colorado (http://co.water.usgs.gov/projects/rcmap/), and North Carolina (at Western Carolina University). An excellent summary of physical and ecological principles in stream restoration is available in the Federal Interagency "Stream Corridor Restoration" manual (http://www.nrcs.usda.gov/technical/stream_restoration/).

Viewing Stream and River Restoration in Context
It can be useful to view restoration opportunities in the context of a continuum from fully urban to wilderness conditions (see Figure 1).

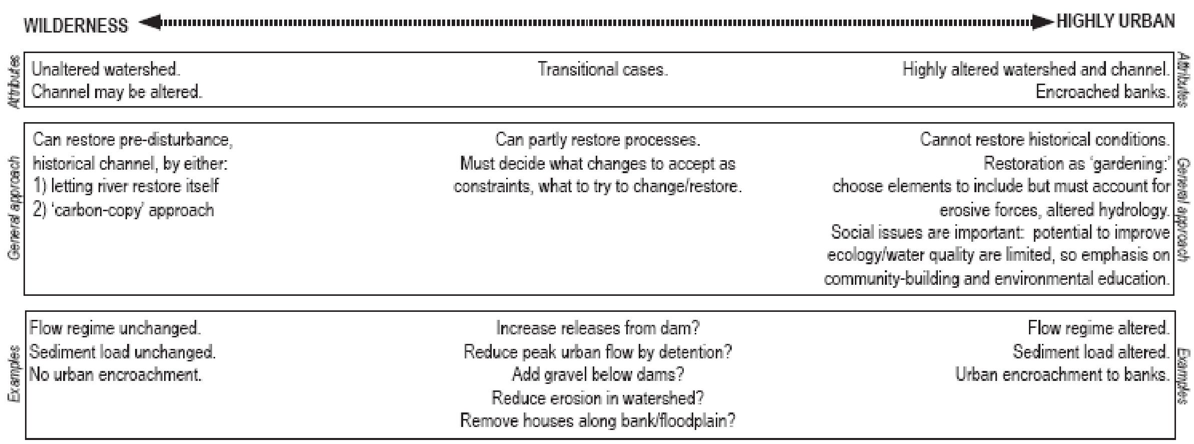


Figure 1 – Continuum from wilderness to highly urban settings for stream/river restoration projects.

Using stream restoration to illustrate the idea that stream and river restoration projects should be viewed along a continuum from wilderness to highly urban, first consider that geomorphic theory suggests that alluvial channel geometry and dimensions will reflect the independent variables of flow and sediment load (Skabelund and Kondolf 2007). In wilderness settings, where flow and sediment load from the watershed are essentially undisturbed, it follows than that we could recreate (in an artificially straightened and widened reach, for example) the historical, pre-disturbance channel form, and expect that it will be in equilibrium with the prevailing flow and sediment load. This is the *carbon copy* approach, in which we mimic pre-disturbance, equilibrium forms (Brookes and Shields 1996). In fact, if the river has high stream power and adequate sediment load, over the course of several floods, the channel could be expected to evolve on its own back to its pre-disturbance, equilibrium form provided we released the river from its artificial constraints (such as rock bank protection).

By contrast, in densely urban settings, where runoff and sediment load have been profoundly altered and urban development has commonly encroached to channel margins, it is not possible to allow physical processes to operate freely, as the channel will typically incise and widen, wreaking havoc with urban infrastructure. Moreover, in such settings the ecological potential of the channel is severely limited, and the greatest potential benefits from the channel are those related to social benefits from creating trails, parks, and other opportunities for public use and education. In this urban extreme, we can view restoration as comparable to *gardening*: we can select elements to include, such as trails, picnic areas, playgrounds, trees, shrubs, etc…, but we are placing the elements in the landscape. Moreover, urban channels have a tendency towards incision and channel widening from sediment-starved runoff, with peak flows increased by the extent of impermeable surfaces in the catchment. Thus, such urban channels typically need to be hardened to withstand highly erosive forces during high flows (for example, by appropriate use of boulders, rip-rap, bio-engineering, or other tools and techniques well-suited to the hydrologic and geomorphic characteristics of the site and its larger drainage area or watershed).

The wilderness and urban extremes of the continuum are relatively straightforward, in that they offer distinct opportunities and constraints. However, we often find ourselves faced with a situation intermediate between these extremes, where some processes have been altered, but there is some flexibility. An example would be a river channel downstream of a dam, where flood peaks have been reduced, and the seasonal hydrograph altered. Before we can design a sustainable restoration project, we must decide whether we (1) accept the altered hydrograph as a constraint, and design our restoration for the reduced flow regime, or (2) work with river managers to increase the high flow releases to (at least partially) restore the natural flow dynamics. In other words, we must decide whether we accept hydrograph alterations as a constraint to restoration, or whether we try to (partially) restore hydrologic processes. This is a critically important decision, with many ramifications for future management. And it is fundamentally a social decision. Science cannot provide “the answer”, but it can inform the decision-making process (Skabelund and Kondolf 2007).

In the first case, if we accept the dam-altered hydrograph as a constraint, our restoration actions are attempts to recreate natural river characteristics on a reduced scale, in effect a scaled-down version of the original river. In the north-central interior of California, most rivers are impounded, with substantially reduced flood regimes and sediment supply. There, experimental programs are ongoing to create dynamic rivers that are scaled down to the dam-altered hydrographs, such as on the Trinity River (USFWS and Hoopa Valley Tribe 1999).

Not everything scales down easily. For example, for spawning, salmon need gravels within a certain range of sizes, and these gravels need to be mobile frequently enough to flush fine sediment and maintain a loose structure (Kondolf 2000). However, if we have accepted smaller floods, that limits the size of gravel we can have in the channel that will still be mobile under the post-dam flow regime. Or put another way, the gravel of suitable size for spawning may be too large to be moved by the post-dam floods. Another important issue in such a reach is that the dam traps sediment supply from upstream, releasing sediment-starved, or *hungry water,* which tends to erode the bed and banks to compensate for its lack of sediment load (Kondolf 1997).

There are many other such issues that arise in planning restoration in situations in the middle zone of the wilderness-urban continuum. For example, we may seek to restore floodplain connectivity with the channel, but houses have been built in the floodplain. Do we accept these as an immutable constraint, and conclude that we can no longer have frequent overbank flows, or do we explore opportunities to move the residents to higher ground (as done in some towns along the Mississippi River after the 1993 floods) or build ring dikes around small settlements while allowing most of the floodplain to flood? Again, these are decisions that will reflect society’s values, but which we can inform with good science and environmental planning (Skabelund and Kondolf 2007).

The emphasis on restoring pristine conditions, and arguments about whether that is possible, often miss the point that our society has irreversibly altered the landscape in most places. It is rarely possible to restore “pre-disturbance” conditions. Restoring functional attributes desired for the system is generally the most sensible approach (Kondolf et al. 2006).

Recognizing and Appropriately Addressing Project Constraints

In the urban context it is rarely possible to restore a segment of stream to pre-development conditions. Given urban development (existing and expected), we must ask if our efforts will be adversely impacted by increased rates of stormwater runoff from above our project site as well as by more intense or frequent flooding over time. We must also consider property ownership, land use, and invasive species issues surrounding the reach of stream we desire to restore. Our hope may be to restore the stream channel to pre-development conditions, but this ideal is generally not feasible nor expedient. A better approach may be to work with property owners along the entire length of the stream in order to reduce stormwater inputs and to restore the riparian corridor as best as possible by using various best management practices, including location-and-geomorphic-appropriate planting/seeding and bank stabilization schemes.

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