Aging infrastructure and the future of the concrete channel: drivers and barriers to re-invention

Nouvelle vie pour des anciens chenaux en béton : les motivations et les obstacles

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RÉSUMÉ

Le chenal en béton était une technique répandue pour « maîtriser » les inondations urbaines et encourager l'aménagement des plaines d'inondation. Aux États-Unis, entre les années 1950 et 1970, de nombreux chenaux bétonnés ont été construits. Cependant, ces structures souffrent de problèmes écologiques mais aussi de problèmes de performance et d'entretien. La conception de ces projets n'a pas pris en compte l'impact des sédiments sur la capacité des chenaux, et ces structures vieillissantes sont de plus en plus difficiles à entretenir. Elles n'apportent pas la protection escomptée contre les inondations, et comme ce sont des structures très rigides, elles ne se prêtent pas à l'adaptation. Ces projets à visée trop restrictive ont considérablement supprimé les habitats riverains, et les aménagements des plaines d'inondation qui en résultent s'étalent jusqu'au bord même des chenaux, ce qui limite les options de restauration. Des exemples de restauration de chenaux de crues sur les fleuves du Los Angeles en Californie et du Kinnickinnic dans le Wisconsin montrent les possibilités de réinvention de chenaux de crues. Pour ce qui est de la restauration ou réhabilitation de ces chenaux, nous identifions les contraintes et les possibilités en matière des organismes gouvernementaux, du soutien public, de la hiérarchisation des priorités, de la planification hydrographique, des directives techniques ainsi que des responsabilités.

ABSTRACT

Concrete channel was a common technology to 'control' urban flooding and encourage floodplain development. In the United States many concrete channels were built between 1950s and 1970s. However, these structures are plagued with performance, maintenance and ecological issues. Project design did not account for sediment effect on channel capacity, and the aging structures are increasingly difficult to maintain. They cannot provide flood protection as designed, and as rigid structures, they are inflexible to adapt. These narrowly focused projects significantly eliminated the riparian habitats, and the resulting floodplain developments often encroach right up to the edges of these channels, limiting available options for restoration. The flood control channel restoration examples at the Los Angeles River in California and Kinnickinnic River in Wisconsin show the possibilities to re-invent concrete channels. We identified constraints and opportunities in government organizations, public support, improvement prioritization, long range catchment planning, technical guideline, and liability, to restore or rehabilitate these channels.

KEYWORDS

Concrete Channel, Operation and Maintenance, Restoration, Urban Flood Control

1 CONCRETE CHANNELS IN THE UNITED STATES: STATUS AND FUTURE

Concrete channels are intended to maximize flow velocity, minimize required channel area, and minimize required maintenance. Concrete channel were widely embraced as a promising solution to "control" floods and increase floodplain development in urban areas. The U.S. Army Corps of Engineers (USACE) is responsible at the federal level for flood control, under the Flood Control Act of 1936, which requires a cost-benefit analysis for project feasibility evaluation. Cost-benefit analysis has been problematic. For example, in the San Francisco Bay region (Wong and Kondolf 2015, in prep), many projects were justified based on "land enhancement" benefits, that is, the value of property that could legally be developed on the floodplain or former marshland next to the channel because of the flood protection – even though the development was environmentally destructive and increased residual risk. Rising environmental awareness in the 1970s reduced public support for flood control projects, such that at the federal level there was no major USACE flood control project authorized between 1970 and 1985 (Carter and Stern 2010).

There are over 4800 km of flood control structures (levees and channels) in California. Many of these are legacy concrete channels. Rivers managers in California and throughout the nation are now facing the difficult choice on reinventing versus maintaining these aging infrastructures. At a conference on the Future of the Concrete Channel (University of California Berkeley, 2013), practitioners, managers, and researchers shared ideas and experiences, and explored options for the concrete channel from multiple perspectives, yielding the findings summarized here.

2 CONCRETE CHANNEL PERFORMANCE AND MAINTENANCE ISSUES

The promises of reliable flood control and low maintenance are repeatedly tested. Concrete channels provide some level of flood reduction, but there are notable cases of performance failure due to faulty design assumptions and maintenance requirements beyond the capabilities of the local sponsors.
One such example is the Corte Madera Creek, which drains 72 km^2 catchment to San Francisco Bay. Severe flooding in the 1950s prompted construction of earth and concrete flood control channels in 1960s and early 1970s. The project channel capacity was exceeded in 1982, 1983 and 1986, and forensic investigations indicated that the original design underestimated sediment transport and deposition effects on channel roughness, resulting in an overly optimistic estimate of channel capacity. Since the concrete channel were designed with 0.3 m freeboard under supercritical flow, higher channel roughness results in subcritical flow and overtops channel banks.

Typically local agencies are responsible for channel operation and maintenance. Although these channels were constructed assuming low maintenance, structural deterioration, sediment deposition, in-channel vegetation, habitat destruction, floodplain development, and conflicting permitting requirements introduced significant management burdens. Contra Costa County, California, estimated over $2.4 billion dollars is needed for infrastructure replacement, in addition to annual operation and maintenance cost. In the Kinnickinnic River in Milwaukee, numerous concrete slab structures have failed, costing around $250,000 in each repair, in addition to ongoing sediment and vegetation maintenance along the channels and wood debris removal at culverts. Of nine USACE flood control channels in San Francisco Bay region reviewed by Wong and Kondolf (2015, in prep), none of these project were fully maintained with respect to channel sedimentation, and most do not provide the design flood protection level. Urban development right to the bank edge limits access to channel maintenance and future reinvention opportunities.

3 REINVENTING CONCRETE CHANNELS

One of the most notable concrete channel in the United States is the Los Angeles River in Southern California. The 82 km long river drains a 2250 km^2 catchment from San Fernando Valley to San Pedro Bay. After severe flooding in the late 19th and early 20th centuries, a concrete channel system was constructed in 1959 (USACE 2013). Hailed at its completion as an engineering masterpiece, it eliminated many km of habitat and open space now lacking in the overbuilt urban landscape. In 2013, USACE proposed to restore 18 km of the Los Angeles River near Glendale to provide floodplain expansion and hydrologic connections. The selected Alternative 20 (with strong local support) will cost $1.08 billion, of which 46% is real estate cost funded by the local agencies. Despite this significant cost, the project is expected to increase community value, and enhance ecological and water quality.

The Milwaukee Metropolitan Sewerage District (MMSD) plans to remove 3.2 km of concrete channel in Kinnickinnic River to provide social, ecological, and public safety benefits. The approved alternative plan in 2009 included purchasing 83 homes near the river. MMSD started purchasing homes through voluntary sales in 2010, and concrete channel removal and new channel construction is underway.

These two examples showed that while the option to restore concrete channels to "natural" channels is promising to reinvent concrete channels, there are significant challenges such as right of ways, permitting, and funding. To complicate the issue, there are many forms of barriers, which can change with time. Engineers define it as a science and mathematics problem, project owners define it as finance and political problem, and community members tend to define it as environmental and economic problem.

4 CONSTRAINTS AND OPPORTUNITIES TO REINVENTION

Government Organizations: Multiple agencies have overlapping and often conflicting jurisdiction over rivers, and the USACE is perceived by some local agencies as a hindrance because of its regulatory requirements and funding limitations. The Federal Emergency Management Agency (FEMA) flood insurance program discourage reinvention, since the program only considers the existing flood condition, and the policy encourages in-kind floodplain development replacement after natural disasters. Local flood control agencies are becoming *de fecto* river managers but with limited mission, power, and resources on multi-objective river management. Land use decision made at the local municipal level may not be consistent with state and federal policy.

Public Support: The success story at the Los Angeles River ecosystem restoration project is partly credited to strong public and community groups supports. It is important to communicate our vision and goals that elicits understanding and resonates with the public. The terminology in public communication not only should accurately convey project goals, but avoid giving a false sense of security in the absence of major floods. The FEMA floodplain maps are not sufficient to communicate flood risk because of the significant residual flood risk above the 1% flood. Conference recommended a new series of floodplain maps be created based on (1) an extreme storm event such as ARkstorm in California, and (2) built-out catchment hydrology with historical natural watercourse.

Improvement Prioritization: To effectively manage the aging infrastructure with limited resources, we need to assess the infrastructure condition, estimate remaining service life, and prioritize improvement needs. Currently, there is no national flood protection infrastructure master plan. Such master plan is helpful to manage the aging infrastructure, but it requires significant federal resource and funding commitment. A state or regional level master plan study could be feasible. The master plan develops a structured approach to assess existing condition and performance, develops deterioration curves for estimating remaining service life, and develops and prioritizes improvement needs.

Long Range Catchment Planning: One of the most critical constraint for concrete channel removal is the available space for lateral river corridor expansion. For local flood control agencies, there are three barriers to this constraint: lack of landuse authority, local land use decisions favor urban development over floodplain preservation, and knowledge gap on the space requirements for restoration. Catchment based planning can provide a systematic framework to examine multi-objective options (water supply, sediment reuse, habitat restoration, and flood management) across the watershed, and the foresight to plan for right-of-way acquisition and opportunistic urban stream restorations. In addition, Hurricane Katrina and Hurricane Sandy illustrate the potential for major disasters to provide opportunities for large scale improvement works. A long range plan will ensure that the improvement is not just to rebuild in-kind since there is a lack of better options. For example, Contra Costa County adopted a 50 year plan in 2009. This long range plan layout the foundation to develop community consensus and public support on improving the County’s creek system. Policy makers should develop mechanisms to require or incentivize catchment based long range planning.

Technical Guidelines: There is a disconnection between the precision of design and the precision of science. Most flood control projects are based on the 1% flood design criteria. However, estimating the flow rate and stage of this 1% flood is not an exact science. When public agencies and private developers try to pursue sustainable flood management design or channel retrofit, there are no broadly accepted guidelines. Many current designs are driven by regulatory permitting requirements. For each concrete channel removal project, we are creating a new ecosystem which needs a precise description. The professional community needs a new set of guidelines on how to manage existing aging infrastructure and design new flood reduction projects that are more sustainable. Examples could include updating USACE design manuals on hydraulic design and risk and uncertainty analysis, and develop a systematic guideline on condition assessment for local flood control agencies.

Liability: Modifying existing concrete channels could trigger significant liability risk to the owner of the facilities, the agencies responsible to the public for flood protection, and designers for the project.

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