CALFED BAY-DELTA PROGRAM

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To: John Kirlin, Executive Director
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From: Mike Healey and Jeff Mount, Science Advisors to Delta Vision Blue Ribbon Task Force

Subject: Delta Levees and Ecosystem Function

Introduction

This memo discusses the impact of Delta levees on ecosystem function. Earlier drafts of the Vision suggested that the current configuration of levees in the Delta was important for sustaining ecosystem function. The most recent drafts do not make this assertion but we understand that some Task Force members believe that the levees are important for ecosystem function. Although the Delta levees are important to many human uses of the Delta, we do not believe they are critical to ecosystem function. Indeed, as we describe below, the construction of Delta levees transformed a tidal freshwater marsh into a mosaic of farms surrounded by tidal channels. This transformation of the Delta by levees, with the concomitant loss of more than 90% of its original marsh and riparian habitat is one underlying cause of ecosystem decline in the Bay-Delta estuary. Levees are, however, critical to many present-day uses of the Delta and the levees cannot be completely abandoned even if the resulting ecological benefits were projected to be huge. Additionally, simply allowing the levees to fail on deeply subsided islands would not generate any obvious ecological benefits. Nevertheless, we judge the present system of levees in the Delta to be unsustainable. We recommend that land and water managers, and private interests engage in a meaningful evaluation of levees and land use in the Delta so that both land and water use can be made sustainable over the long term. Simply waiting for the next big earthquake or major flood to decide these things for us is not a strategy for sustainability.

Bay-Delta Estuary Functions versus Levee Functions

The Bay-Delta is a floodplain estuary. Floodplain estuaries are among the planet's most highly productive ecosystems. Their high productivity is driven to an important degree by an intimate relationship between land and water. In a natural tidal marsh, twice-daily tides cause water to overflow the tidal creeks and flood the marsh plain as the tide rises, delivering sediment, nutrients and organic material that nourishes the marsh. As the tide falls, it draws nutrients, sediment and organic material off the marsh plain and into the tidal channels where it is distributed to other parts of the estuary. The seasonal changes in river flow behave in a similar way but on a slower rhythm, flooding onto the floodplain during flood flows and retreating into the main channels during low flow, mobilizing, distributing and redistributing sediments, nutrients and organic material. When water flows onto the floodplain or marsh, mobile small fish and other organisms rush out of the channels to feed on the plain of the marsh or floodplain, then retreat back into the channels again as water level falls. This is an important mechanism for providing sustenance to estuarine foodwebs. Tidal and riverine flow regimes interact to create a complex pattern of flooding and drying that changes with the seasons and the phases of the moon and is a root cause of the extraordinary productivity of floodplain delta/estuaries. The construction of Delta levees blocked the complex exchanges between land and water that supported biological productivity in the Bay-Delta estuary. Conversion of more than 90% of marshland to farms (and more recently, urban uses) ended the tidal and seasonal exchanges of water, energy and materials between the land and the open water channels of the Delta. In addition, levee construction upstream of the Delta eliminated important food subsidies to the Delta that seasonal inundation of the river floodplains provided. In effect, levees have disconnected the Bay-Delta estuary waters from important historic food and energy sources, and established new forms of land use, greatly changing the ecological function of both water and land. The aquatic system of the Bay-Delta estuary is now much more a system of open water basins and channels dependent almost entirely on *in situ* primary production to sustain its ecosystem. Wetland and terrestrial ecosystems have been transformed, simplified, fragmented and cut off from direct connection to the open water system. Even where substantial marshes remain (Suisun Marsh for example) the ecological coupling between open water and marsh is not strong because the marshes are managed for waterfowl.

Open water, marsh and upland species have all been impacted by this transformation of the Bay-Delta estuary and some struggle to persist in the current environment. Pelagic species have received much attention recently because of the potential impact of water exports on their survival. However, it is important not to lose sight of the fact that ecosystems and ecosystem processes on both sides of the levees have been dramatically altered by construction of the levees.

Ecosystem Restoration and Levees

Much of the emphasis in the CALFED Ecosystem Restoration Program and in recent debates about restoration in the Delta has focused on increasing the areas of marsh and floodplain that are connected to the water so that they flood on seasonal and tidal cycles. This kind of restoration, which involves levee set backs, some levee breaching and changes in the freshwater flow regime, attempts to reestablish some of the complex historic connection between land and water, improving the capacity of the Bay-Delta estuary to sustain its native species. But there are uncertainties that need to be acknowledged. Given species invasions, it is not certain that this kind of restoration will benefit all valued native species, especially in areas where invasive species have come to dominate. In particular, marsh restoration may not provide much benefit to the pelagic fishes that are the focus of such recent concern. Other species will benefit, however, and increasing land/water connectivity will increase exchanges of energy and materials between the land and water, thereby increasing ecosystem resilience.

The many hundreds of miles of levees in the Delta are intended to prevent flooding of adjacent lands or to protect navigation. Some scientists argue that the design of channels and levees in the Delta creates hydrology that homogenizes water characteristics through much of the Delta, to the detriment of native species, including pelagic fishes. Reestablishing a hydrology that is more variable in time and space may be more important for conserving pelagic species than constructing marshes or opening floodplains. In the Delta, the effect of levees and other channel modifications has been to simplify and homogenize the open water system, possibly facilitating the establishment of dense monocultures of species like the Asian clam and the overbite clam. A more variable hydrology with its attendant variation in water residence, temperature, nutrients, turbidity and other factors might create combinations of factors in some places and at some times are highly favorable to native species, thereby assisting their recovery. Levees could be used as barriers or deflectors to complicate flow patterns and increase heterogeneity.

There is a common misconception that levees create value as upland habitat but they do not. Today's levees have little in common with historic natural levees. The nutrient cycling, forest succession, woody debris recruitment and complex shallow water habitat that formed as part of the dynamic natural levee system is largely missing from today's levees. Modern levees are narrow, steep sided, sparsely vegetated strips of land that are fixed in space and time. Furthermore, even if levees were targeted for habitat improvements, current state and federal regulations that require extensive maintenance, erosion control, and vegetation removal limit their habitat value. Dual levee systems that provide habitat value together with increased levee integrity can be constructed at considerable cost. But such a levee system is deliberately designed for dual function. Habitat is not a natural consequence of levee construction.

Where natural marsh habitats are of limited extent, levees can be used to ensure that some areas of freshwater marsh can be sustained in places that would otherwise be entirely tidal brackish or salt marsh. To some extent, this is done in Suisun Marsh. However, this is a deliberate use of levees for habitat management purposes, principally waterfowl management in the case of Suisun Marsh, not a normal consequence of levees.

Lands protected by levees can be used for various types of wildlife friendly agriculture, a multiple use that combines conservation with continued agricultural production. Such lands should be protected by levees but this is also a deliberate habitat management use of levees and may be no better ecologically than allowing intermittent flooding of the same lands. Reversing subsidence on subsided islands by growing tules is also a potential conservation measure that would depend on levees to manage water levels while the tules grow. However, this is also a deliberate conservation use of levees, not a natural consequence of levees.

One possible use of subsided islands involves digging out the centers of the islands and using the material to create a shallow slope on the landward side of the levee, providing the island with additional protection from levee failure. The island could also be flooded to create a ring of shallow water habitat around the edge of the island for waterfowl, tule growing, and some forms of recreation. Levees would play an important role in this use of islands but in the context of a deliberate conservation program, not a natural consequence of having levees.

Catastrophic Levee Failure and Ecosystem Function

Recent reports prepared for CALFED, DWR, and Delta Vision have all pointed to the same conclusion; massive levee failure in the Delta, whether due to earthquake or floods, would have serious social and economic consequences. The ecological consequences of massive levee failure are less obvious. The ecosystem effects would depend on the human response to such an event. If all levees were repaired and islands pumped dry, ecological effects would be mainly short term and any fish or other organisms that invaded flooded islands would be destroyed (note the recent press reports of fish kills as Prospect Island is pumped dry). If islands were left flooded, the impacts would depend on: 1) the locations, sizes and depths of the flooded islands; 2) the configuration of levee breaches; 3) the influence of flooded islands on hydrodynamics; and 4) how native and invasive species responded to the new environment. There would probably be both positive and negative ecological consequences of massive levee failure but attempts to determine these have so far been rushed and controversial (e.g., DRMS process). Short-term consequences would probably be mostly negative but the balance of long-term consequences is difficult to predict. Indeed, several of our colleagues have suggested that, over the long term, positive and negative ecological effects of multiple levee failures might be about equal. Given its devastating social and economic implications, massive levee failure is to be avoided. However, it is neither practical nor feasible to protect and sustain current land use on heavily subsided islands for much longer. The likelihood of a levee-breaking earthquake in the next 30 years is very high. There is an urgent need to develop alternative and more sustainable visions for the future of these islands.

Conclusions

In summary, the current levee system does not contribute to improved ecosystem function in the Delta. Rather, the construction of Delta levees precipitated an ecological transformation involving both the land and the water and has probably been a cause of many current ecological problems. Today, levees can be (and commonly are) used for conservation purposes. Levees are used to control water quality or hydrology to promote specific habitat types (such as waterfowl habitat). Where lands are not heavily subsided, levees can allow for multiple land uses including habitat management and wildlife friendly agriculture. Where feasible, levees should be removed to allow natural or engineered restoration of seasonal and tidal wetlands, thus restoring some of the historic land/water connection that supports estuarine productivity (e.g., Liberty Island). For deeply subsided islands, current land use is not sustainable and there is a critical need to work out more sustainable land uses. Given current trajectories of sea level rise, land subsidence, seismic risk, and flood risk, the Task Force can presume that a significant portion of the deeply subsided western and central Delta will transition to open water habitat. This transition will establish a new ecosystem with new attributes creating new management challenges. The uncertain ecological consequences of such a transition will include both positive and negative effects, but the social and economic consequences would be devastating unless steps are taken at once to smooth the transition.

Respectfully,

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