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DRAFT M E M O R A N D U M

DATE: May 16, 2005

TO: Kate Bolton

COMPANY: University of California, Berkeley – Capital Projects

FROM: Andrew Collison

COPY TO: Jorgen Blomberg, PWA
Jeffrey Haltiner, PWA

RE: Winter Creek Geomorphic Assessment - DRAFT

PWA Ref. #: 1773.00 - Winter Creek Stabilization and Enhancement Project

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This memorandum describes the Winter Creek geomorphic assessment performed by PWA in support of the Winter Creek Stabilization and Enhancement Project. The geomorphic condition of the channel was examined between the culverts at the upper and lower end of the proposed project reach in the UC Botanical Garden's Mather Memorial Redwood Grove.

Background

Winter Creek is a steep headwaters creek, with a watershed area of 53 acres (0.08 square mile). The upper watershed (34 acres) is very steep and forested, while the lower watershed (19 acres) is slightly less steep and includes a mixed land use of grassland and developed areas (Lawrence Berkeley National Laboratory). Significant development (building, roads and parking lots) and land use change (Eucalyptus removal and stormwater system improvements) in the lower area have occurred since 1989.

In the project reach, the creek has an average gradient of 16% between the invert of the upper culvert and the invert of the lower culvert (assumed to represent the approximate gradient of the creek at the time the culverts were constructed). Creeks of this type are typically slightly incised (have steep, 'V' shaped banks approximately 4 -10 feet high) and have a boulder-dominated step-pool form (their channel beds form a staircase of small vertical drops of approximately 1 foot in height with flatter/ lower gradient sections typically ranging from 5 to 20 feet long between each drop).

Geomorphic Assessment

In Winter Creek, the upper reach of the channel has incised greatly below the upper culvert outfall. This incision has created a 9 to 10 foot vertical drop and scour pool just below the culvert. The culvert apron (grouted rock) has subsequently collapsed and broken apart causing flows to dissipate directly onto the creek bed. The banks in this upper section of the creek are vertical to overhanging, and are up to 15 feet high. The incision observed appears to have occurred due to both erosion below the culvert outflow and erosion that migrated headwards (upstream) from the lower reach to the culvert. The eroding channel is actively undermining the existing culvert outfall and is anticipated to continue to migrate upstream, which could destabilize the culvert, pathway and areas upslope. Although the erosion below the culvert is most dramatic, there are several smaller knickpoints downstream of the culvert that are also likely to migrate headwards, causing further channel incision upstream. These smaller knickpoints are dynamic and critical factors to address in any future culvert protection/ channel stabilization scheme constructed upstream of these locations. Without consideration and appropriate treatment of these knickpoints and their potential future evolution, project stabilization measures may be undermined.

In response to the channel downcutting, significant sections of the banks in the upper reach are actively slumping, in several cases causing trees to lean and fall, and ultimately to die or become safety hazards. In the lower reach of the project, the banks are also eroding; however these banks are lower than those upstream and do not support large, specimen trees. Several areas of slope above undercut stream banks are close to or at their angle of repose (material on them slips under any disturbance). As a result any continued channel erosion is likely to trigger slumping on the slopes above. This is likely to continue and possibly worsen until the channel incision is stopped, or partially reversed.

Channels with erodible beds and banks adjust (by erosion and deposition) until they have a shape and gradient that is in equilibrium with their sediment and water inputs from upstream (Figure 1). Equilibrium is defined by a balance of erosion and deposition over a long period of time that results in no net change in bed volume and slope. When the water or sediment inputs are altered the channel adjusts to equalize the energy imbalance. Based on our hydrologic assessment of the watershed (PWA, 2005) urbanization/ land use change appears to have increased peak flows by approximately 30% during the five-year flood. When water inputs to a creek reach increase (increasing energy) the typical channel response is to downcut until the channel has created a lower gradient, absorbing the surplus energy and so regaining geomorphic equilibrium. Since the downstream culvert at Centennial Drive forms a fixed point (grade control) for the channel, the adjustment 'hinges' upstream above this point. We expect that increased and ongoing incision will occur upstream away from the culvert until a new hard point is reached.

Based on evidence (UC observations, 3/2005 communication) that the creek was stable for a considerable period of time after construction of the culverts and prior to development upstream, we assume that the slope between the upper and lower culvert inverts (16%) approximates the equilibrium channel gradient for the hydrologic regime of the watershed at this time (prior to 1989). The stable gradient may be moderately lower if we assume that the upper culvert installation was modified to facilitate the construction of the access path over it near the entrance to the grove. Between the knickpoints in the lower reach there are several short sections where the channel appears to have regained a relatively stable condition with the new flow regime. These channel sections provide evidence of the maximum gradient at which the creek would be stable overall. For example, between channel stations 190 and 260 feet (see

Figure 2) the channel appears to be relatively stable, with a gradient of 9%. We can compare this with equilibrium gradients recorded in east Contra Costa County for creeks with a similar watershed area, but consisting of finer bed material. In east Contra Costa County equilibrium slopes for channels with similar watershed areas had gradients of around 2%. We should note however, that the Contra Costa channels surveyed were composed of significantly finer material, and so adjusted to lower gradients than would be the case for coarse bedded streams such as Winter Creek. Slope values of 2% and 9% probably bracket the lowest and highest equilibrium gradient under current watershed conditions. If the amount of impermeable area in the watershed increases in future, the upslope drainage network is lengthened by drainage work, or sediment supply is reduced because of erosion control work, the new equilibrium gradient will be even lower. Balancing the coarseness of the local sediments and sediment supply with the need for conservatism and the potential for further development in the watershed, a stable gradient of 4-5% appears appropriate.

The channel instability that is occurring in Winter Creek has established an active cycle of erosion that is expected to continue for the foreseeable future regardless of modifications/ reductions to the hydrologic input to the channel. Through communications with UC staff we understand that the catastrophic erosion observed in Winter Creek has occurred over a relatively short period of time (2- 4 years). It is difficult to estimate the potential rate of future erosion, however we expect that bed erosion and bank instability will continue. If the channel is left untreated, incision will continue until the creek has an average gradient between 2% - 9%. Assuming the creek equilibrates to a slope of 9% (the most optimistic scenario) this will involve an additional 20+ feet of incision below the culvert at the upper end of the reach, with commensurate erosion, bank failures and lateral adjustment expressed along the channel. Bank instability and failure associated with future channel incision will threaten existing trees, planting areas, infrastructure and utilities. For discussion purposes; assuming an equilibrium slope of 2% within the project reach, the anticipated erosion could be more than three times greater than that expected from at stable 9% slope. For this reason we recommend a program to stabilize the channel in the near future to preclude further incision and subsequent on-site, downstream and upstream impacts.

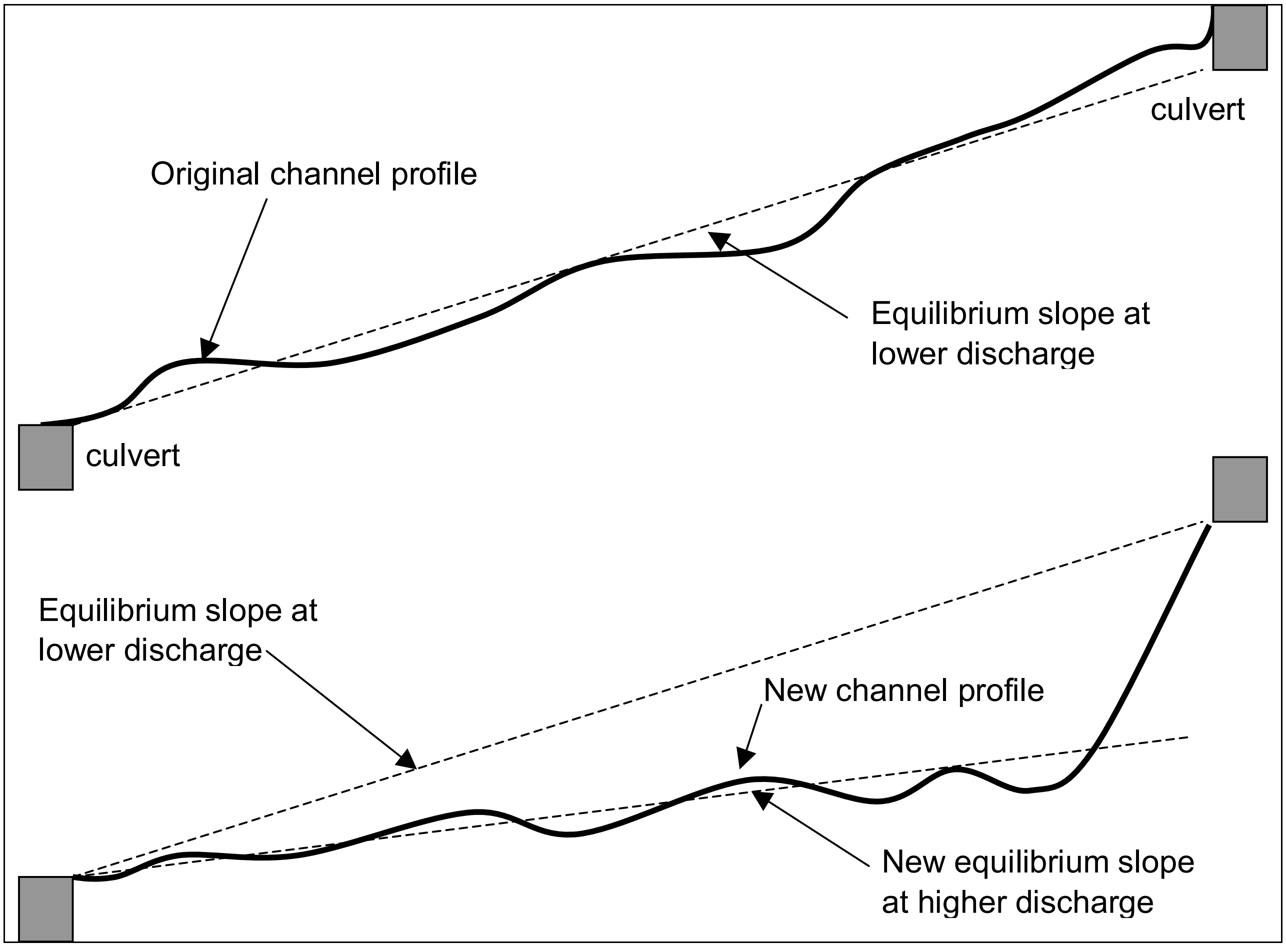

Figure 1. The equilibrium slope concept.

Recommended Remedial Action

From a geomorphic perspective the preferred approach is to stabilize the channel invert, then address adjacent bank stability issues. The channel invert can be stabilized by constructing a series of step-pool structures with approximately 2-3 foot drops (ramp/ staircase structures take up excess vertical drop), linked by sections of channel built to equilibrium grade (~5%). The step-pool structures must be permanent elements that hold the channel in place. The step-pools will gain the necessary vertical height difference between the equilibrium grade and the grade between the culverts, while dissipating excess energy. The 5% channel sections should also integrate smaller step features, however these steps can be designed and constructed as more 'flexible' features that adjust accordingly during flood events. During large flood events the smaller steps may change shape, but the overall creek bed will be held in place by the larger structures.

A number of different structure types and materials can be considered for the design and installation of channel stability structures. The structures and materials must account for:

- Existing and potential hydrologic conditions
- Hydraulic forces (velocities, shear stress, water surface elevations)
- Geomorphic processes
- Capture of surface and subsurface flows
- Constructability
- Integration of biotechnical/ revegetation elements
- Durability/ Material life
- Aesthetics and Visibility

In addition to these on-site measures, the project reach, and other downstream channel sections would benefit from measures to reduce the increased flow regime from upstream. This could include any number of Low Impact Development (LID) measures designed to reduce the increased flow peaks and volumes from upstream. Potential features could include detention basins, infiltration methods, disconnected paving etc.