PWA
PHILIP WILLIAMS & ASSOCIATES
CONSULTANTS IN HYDROLOGY
720 CALIFORNIA ST., 6TH FLOOR, SAN FRANCISCO, CA 94108
TEL 415.262.2300 FAX 415.262.2303
SFO@PWA-LTD.COM

MEMORANDUM

DATE: May 4, 2005

TO: Kate Bolton

COMPANY: University of California, Berkeley – Capital Projects

FROM: Amy Stewart, Matt Wickland, PWA

COPY TO: Jorgen Blomberg, PWA
Jeffrey Haltiner, PWA

RE: Winter Creek Hydrology Calculations

PWA Ref. #: 1773.00 Task 1 - Winter Creek Stabilization and Enhancement Project

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This memorandum describes the Winter Creek watershed hydrologic calculations developed by PWA in support of the Winter Creek Stabilization Project. Peak creek flow rates are estimated for the Winter Creek watershed at the junction with Centennial Drive (upstream of the Mather Memorial Redwood Grove in the UC Botanical Garden) and also at the base of the stabilization project reach (approximately 500 ft downstream of the Centennial Drive junction). Calculation of Winter Creek peak flows will aid in the upcoming PWA stabilization design of the Winter Creek channel within the Redwood Grove.

Discharge peaks were calculated for existing (year 2005) conditions and, for comparison, land use conditions representative of 1989. Between 1989 and 2005 significant vegetation removal, grading, and building construction occurred thereby altering the watershed hydrology.

Hydrologic Model
Measured streamflow rates are not available for the project area. Therefore a computer simulation program was utilized to convert design precipitation events into predicted runoff flow rates. The U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) model was selected based on its widespread use and acceptability in similar applications. (The USACE developed HEC-HMS to supersede the prior HEC-1 flood hydrograph modeling package.)

HEC-HMS allows user-selection of a range of infiltration mechanisms, runoff hydrograph transformations and channel routing. HMS is capable of continuous runoff modeling in addition to traditional discrete event-based modeling.

Model Parameterization

The HEC-HMS model was parameterized according to methodologies described in the Contra Costa County Water District Hydrology Manual (CCCWDHM). These methods were also utilized in the drainage study (Kuntz, 2004) of the eastern Strawberry Creek watershed (of which the Winter Creek watershed is internal) and are assumed applicable for the study site.

Under existing conditions, the watershed is best represented by an upper, middle, and a lower watershed. The upper watershed contributes runoff to a culvert that runs through the middle watershed (that includes the Department of Energy building complex). Under existing conditions, the upper watershed is steep and forested, the middle watershed is primarily grassland and is less steep and the lower watershed consists of the UC Botanical Garden Mather Memorial Redwood Grove and the parking lot for the botanical gardens. Past (1989) conditions were modeled as two forested watersheds (above and below Centennial Drive), without a culvert or the lower parking lot. Figures 1 and 2 illustrate the land use and watershed boundaries for each scenario. The culvert configuration in Figure 1 is simplified for modeling purposes but is a reasonable representation of the hydrologic/hydraulic system although it may not present real world conditions or extents of the channel and culvert.

PWA used the HEC-HMS hydrologic model to estimate the quantity of storm water runoff occurring due to the five design storm events listed in Table 1.

Table 1. Precipitation Depths

Recurrence Interval, Years	Event Duration, Hours	Cumulative Precipitation, Inches
2	3	1.13
5	3	1.35
10	3	1.85
25	3	2.15
50	3	2.50
100	3	2.70

Source: CCCHM, assuming mean seasonal precipitation of 27.5 inches

The design storms were selected based on communication with UCB staff and recommendations within the CCCWDHM. The Manual does not provide precipitation depths for events with recurrence intervals less than 5-years. Therefore, as advised by CCC staff (Mark Boucher, April 25, 2005) the 2-year precipitation was conservatively estimated based on the trends of the provided precipitation values.

Runoff was calculated using the Soil Conservation Service (SCS) method, which uses runoff curve numbers to represent runoff potential for various soil types and land coverage. Low curve numbers represent a high infiltration potential. In regions where the land cover was identified as structures or paved surfaces, the curve number was set at 98. The curve numbers for grasslands and forested regions was based on SCS's hydrologic soil group C, which is typically defined as a sandy clay loam. Sub-basin average curve numbers were calculated based on area-weighted curve numbers and are presented in Table 2. The curve numbers did not increase significantly above Centennial Drive (between 1989 and 2005) due to the similarities in curve numbers between grassland and tree cover (Hann *et al,* 1994) and also due to the relatively small (less than 5%) increase in impervious area. Below Centennial Drive, in the lower sub-basin, the addition of the parking lot significantly increased the basin impervious area and curve number. The lower sub-basin watershed area in Year 2005 is larger than the lower sub-basin in Year 1989 due to the additional contributing area of the parking lot.

Table 2. Basin Characteristics

Land Use Scenario	Basin	Area, Acres	% Impervious	Impervious Area, Acres	SCS Curve Number
Year 1989	Above Centennial Dr.	52.8	8.9	4.7	73
	Lower Sub-Basin	3.4	7.2	0.2	72
Year 2005	Upper Sub-Basin	33.7	13.5	4.6	74
	Middle Sub-Basin	19.1	12.8	2.4	74
	Lower Sub-Basin	4.5	42.3	1.9	82

Note that all parameters listed in the table have been rounded to the nearest tenth. All calculations were performed within a spreadsheet without rounding.

Watershed time lag is defined as the time interval between the centroid of precipitation and the peak of the discharge hydrograph. For this study, time lag was calculated using the procedures described in the CCCHM. Lag time is represented as a function of basin roughness, length of the primary channel, location of the watershed centroid, and channel slope. As a watershed becomes more developed and the impervious area increases, time lag is expected to decrease. Calculated time lags are presented in Table 3 below.

Table 3. Time Lag

Land Use Scenario	Basin	Time Lag, Minutes
Year 1989	Above Centennial Dr.	15.6
	Lower Sub-Basin	5.1
Year 2005	Upper Sub-Basin	11.2
	Middle Sub-Basin	7.2
	Lower Sub-Basin	3.9

Note that all parameters listed in the table have been rounded to the nearest tenth. All calculations were performed within a spreadsheet without rounding.

Simulation Results

Results from the HEC-HMS model are presented in Tables 4 and 5. Table 4 provides results at Centennial Drive, above the Redwood Grove. Table 5 provides results at the base of the stabilization reach. Peak discharges and event runoff volumes increased for all events with 2005 land use conditions (compared with year 1989 conditions). The largest increase in peak discharge occurred for the smallest (2-year) event. This is expected due to the relative importance of watershed infiltration on smaller events. Increased impervious area results in a decrease in available infiltration.

Table 4. Event-Based Discharge Peaks and Volumes at Centennial Drive (LBNL contribution)

	Year 1989 Conditions		Year 2005 Conditions		
Storm Event	Peak Discharge, cfs	Volume, ac-ft	Peak Discharge, cfs	Volume, ac-ft	Increase in Peak Discharge, %
2-Year	16.5	1.1	21.9	1.3	32.5
5-Year	22.7	1.6	29.5	1.8	29.9
10-Year	38.7	2.7	48.9	3.0	26.5
25-Year	49.3	3.4	61.7	3.8	25.1
50-Year	62.5	4.4	77.4	4.8	23.9
100-Year	70.2	5.0	86.6	5.5	23.3

Source: PWA HEC-HMS simulation results, 2005
Note that all parameters listed in the table have been rounded to the nearest tenth. All calculations were performed within a spreadsheet without rounding.

Table 5. Event-Based Discharge Peaks and Volumes Downstream of the Redwood Grove (LBNL and UCB Contribution)

	Year 1989 Conditions		Year 2005 Conditions		
Storm Event	Peak Discharge, cfs	Volume, ac-ft	Peak Discharge, cfs	Volume, ac-ft	Increase in Peak Discharge, %
2-Year	17.1	1.2	24.9	1.6	45.9
5-Year	23.5	1.6	33.4	2.1	42.1
10-Year	40.0	2.8	54.7	3.5	36.8
25-Year	51.1	3.6	68.8	4.4	34.8
50-Year	64.6	4.7	85.9	5.5	33.0
100-Year	72.7	5.3	96.0	6.2	32.1

Source: PWA HEC-HMS simulation results, 2005
Note that all parameters listed in the table have been rounded to the nearest tenth. All calculations were performed within a spreadsheet without rounding.

The change in hydrology, between the two time periods, is also apparent when viewing the discharge hydrographs at Centennial Drive. The 5-, 25- and 100-year event discharges are shown in Figures 3-5, along with the corresponding 3-hour precipitation hyetograph. As seen in the figure, 2005 peaks are higher and the time to peak discharge is faster than for the year 1989 event.

The above results are comparable to the results of a prior study on the eastern Strawberry Creek watershed. The eastern Strawberry Creek watershed is estimated to produce 1.8 cfs/acre during the 100-year event (Kuntz, 2004). Considering the existing Winter Creek watershed, simulation results suggest that the watershed produces approximately 1.7 cfs/acre under current conditions (96 cfs averaged over a 57.3 acre watershed). Winter Creek and upper Strawberry Creek have similar impervious area percentages (approximately 14%).

Conclusions

Based on the simulations described above, the Winter Creek watershed peak discharge has increased by approximately 24-46% (for the 2- to 100-year events). During the smaller events, the additional impervious surface area in the middle and lower watershed will result in a proportionally greater runoff, since soil infiltration in the natural setting would account for a great percentage of the total rainfall. Within the simulations, hydrologic changes are due to the evolving land uses between 1989 and 2005. Under 2005 conditions, a higher percentage of the watershed is impervious to infiltration. Also, under current conditions, the upper watershed runoff is collected into a culvert and quickly routed through the lower watershed.

In addition, LBNL staff pointed out that several storm-drain inlets and pipes on Grizzly Peak Blvd are regularly blocked or plugged and that runoff occasionally runs to other drains, including drains and pipes that are part of the Winter Creek system. This situation adds flow to Winter Creek albeit episodically and unpredictably. Therefore, we recommend regular monitoring and maintenance of the storm drain system.

Small, steep “headwater” creeks like Winter Creek are particularly sensitive and prone to destabilization from altered hydrology, increased peak flow rates, and increased flow volumes. The increased rate and severity of erosion in Winter Creek at Mather Memorial Redwood Grove in the UC Botanical Gardens during recent years are at least partially attributable to the development occurring in the watershed upstream. PWA did not undertake a survey of conditions downstream of the study area below Centennial Drive, however it is likely that the altered hydrology is also contributing to channel instability downstream of the Winter Creek Restoration project site.

Additionally, given the relationship of development and land use in the upper watershed to channel stability downstream it is important to consider current and future potential land use change in planning for stabilization and enhancement efforts throughout the watershed. Modifications to hydrologic processes and increased runoff specifically, can be effectively accounted for and addressed proactively through different activities (i.e., detention basins, channel stabilization, etc.) and at different locations within the watershed. Further development upstream of Centennial Drive should mitigate onsite for any increased runoff. Approaches to attenuate increased runoff can prevent or limit existing and potential future channel instability and erosion.

References

Hann, C.T, Barfield, B.J., Hayes, J.C. (1994) Design Hydrology and Sedimentology for Small Catchments. Academic Press, Inc. San Diego, CA. 588 pages. .

Kuntz, G.T. (October 2004) Storm Drainage Study of Eastern Portion of the Strawberry Creek Watershed at University of California Lawrence Berkeley National Laboratory. Prepared for the LBNL Facilities Dept.