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Episodic Stream Channels: Imperatives for Assessment and Environmental Planning in California

Proceedings of a Special Technical Workshop

November 8-10, 2010

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Episodic Stream Channels:

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Eric D. Stein, Kris Vyverberg, G. Mathias Kondolf, Kelly Janes

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Acknowledgements

We would like to thank all workshop presenters and participants for sharing their insight and expertise to help develop the conclusions and recommendations contained in this document. We would like to especially thank the workshop organizing committee who made this event possible and Southern California Coastal Water Research Project for providing the venue. Finally, we thank the California State Water Resources Control Board Training Academy for their generous funding and support.

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Episodic Stream Channels: Imperatives for Assessment and Environmental Planning in California

One of the most startling paradoxes of the world's drylands is that although they are lands of little rain, the details of their surfaces are mostly the products of the action of rivers. To understand the natural environments of drylands is to understand the process and forms of their rivers.

W.L. Graf (1988)

Introduction and Workshop Overview

The majority of streams in the arid regions of the Southwestern United States are not perennial; however, the perceptions of how rivers should look and behave are dominated by representations of perennial streams found in humid climates or snowfall regimes. Unlike perennial systems, which tend to reach climax/stable states, the essential quality of rivers in dryland landscapes is the *episodic* nature of flow and sediment transport and the associated dynamism of channel form. A historical focus on perennial systems as preferable, high quality habitat has led to ephemeral and intermittent streams often being characterized as "degraded" and the habitat they provide has been undervalued. However, the health of the entire watershed depends on the health of all its stream reaches. Although these streams function differently than their perennial counterparts, they also provide essential ecosystem services. Recognizing the inherent ecological functions of episodic streams is the first step towards developing and applying conservation and management strategies suited to dryland landscapes.

As the semi-arid landscapes of California face rapid urbanization and initiatives to fast-track construction of renewable energy projects on more than three million acres, there is now an urgent need to incorporate an understanding of the distinctive physical, hydrologic and ecological processes of arid streams to ensure that future developments are sustainable, cost-effective and durable, and include appropriate mitigation measures to offset impacts. In response, the University of California Berkeley, California Department of Fish & Game, and the Southern California Coastal Water Research Project launched an initiative to increase understanding of the physical processes, ecological adaptations, and management/conservations challenges of episodic channels in California, as a basis for delineating and assessing dryland streams and articulating design considerations for future projects. As a first step, the initiative convened a workshop in November 2010 featuring experts on episodic channels and their management. The workshop is followed by publication of these conference proceedings and development of curriculum for agency staff, NGOs, developers, and consultants on identification, assessment, and management episodic channels.

Key Attributes of Episodic Channels

While most of the examples presented are from the Mojave, the symposium also addressed such processes occurring on alluvial fans in more humid regions (such as, Napa Valley), which share many characteristics of dryland streams. Important hydrologic and geomorphic attributes include:

- Highly localized and extremely variable ephemeral and intermittent flow,
- Flood magnitudes much larger (as a multiple of average flow) than conventional humid-climate streams,
- Strong interactions with shallow groundwater, notably rapid infiltration which results in decreasing flow downstream,
- High-volume episodic movement of sediment,
- Unsuitability for application of most hydraulic modeling, and
- Transient forms that confound determinations of active versus relict stream processes and conventional notions of stable and unstable channel form.

The concepts and tools commonly used to evaluate stream behavior were developed in humid and temperate regions, and their transfer to episodic streams in dryland environs can be problematic. For example, hydraulic models commonly assume that channel boundaries will remain relatively fixed, that bedload and suspended sediment will occur in substantially lesser amounts than the volume of water present, that water and sediment move along a channel at a more or less a steady rate, and that water losses along a channel may be considered insignificant – conditions rarely the norm in episodic stream channels. Thus hydraulic models based on such characteristics are problematic as predictive tools for the behavior and evolution of dryland streams over time.

Modification or elimination of ephemeral, episodic dryland streams can severely affect baseflows, groundwater recharge, and the biological communities adapted to the natural hydrology and distributary stream networks. Perennialization of intermittent and ephemeral streams can occur as a result of dams impounding flood flows and releasing steady baseflows, from discharge of treated wastewater effluent or irrigation return flow, or 'urban slobber' from overwatering of landscapes – all contributing to the replacement of a diverse community of dryland species with exotics. Hydrological modifications to such channels can concentrate flows, increase flood intensities, and increase sediment transport and erosion, although the effects of such modifications may not manifest for years or even decades until the next flash flood.

The Symposium

On November 8-10, 2010, 22 speakers and approximately 120 participants from government agencies, academia, and the private sector (see Appendices A and B) gathered in Costa Mesa, California to discuss challenges associated with mapping, assessing and managing episodic streams in the dryland regions of California. The goal of this workshop was to introduce forms, processes, and ecological resources found in episodic stream channels and to provide managers and decision makers with a list of recommended priorities for future work in terms of both technical and management products that will develop our capacity to analyze ecological condition and potential environmental effects of land use decisions.

The workshop consisted of a series of presentations, breakout sessions and a field trip. The presentations began with a discussion of the physical process, landscape influences, and ecology of episodic streams and included discussions of development pressures, regulatory context, and mapping and assessment. This technical foundation was used as a basis to discuss key challenges associated with mapping, assessing and managing these systems.

The participants spent a majority of day two in breakout sessions discussing the following questions and concluded with recommendations for further collaborations, initiatives, and research needs:

- What linkages between the physical processes that sustain or contribute to the integrity of an ecosystem should be preserved by project developments?
- What key field indicators should be used to assess the biological or physical condition of dryland environments?
- What key field indicators can be used to delineate the boundaries of the functional ecosystem in episodic systems?

- What parameters should be included in regional or project-specific monitoring programs to promote improved understanding of the function of episodic systems over time?
- What key limitations of existing assessment tools must be addressed to make them appropriate for use in dryland environments?
- What priority research should be funded to address the limitations or knowledge gaps identified by the questions above?

The third day was devoted to a field trip to the Day Canyon alluvial fan system in San Bernardino County, California where participants were able to observe the principles presented at the symposium plus debate on the ground, the issues highlighted in the workshops.

This document provides a summary of the major topics discussed and the key conclusions and recommendations of the workshop. Detailed summaries of the presentations and additional workshop materials are provided in the appendices. This information, along with complete powerpoint presentations, on the workshops can also be found at www.sccwrp.org, http://episodic.ced.berkeley.edu/ and www.waterboards.ca.gov/water_issues/programs/academy/

We are hopeful that this workshop will serve as launching point for ongoing research and collaboration that will lead to improved tools and capacity to manage episodic streams in an environmentally sensitive manner.

What are Episodic Channels?

Episodic streams are dry or have very low flow for most of the time over decadal time scales. Large events that convey sufficient flow and/or sediment to affect channel morphology occur infrequently (i.e., once or twice per decade) and thus these systems support biological communities that do not depend on a mature, climax, seral state like temperate region streams (Figure 1). Episodic systems exhibit greater variability in channel forms both spatially (different reaches of the same river) and temporally (the same location at different times). Episodic streams have strong interactions with shallow groundwater, and experience rapid infiltration and decreasing flow downstream, and their channel form is periodically "reset" by infrequent, extreme events caused by the local geologic conditions and/or climate as well as by other watershed disturbances such as fire. For example, peak flows in a humid climate or snowmelt/spring-fed systems may be on the order of 20 times the baseflow discharge and may last for months out of every year. By contrast, episodic systems may only flow a few times per decade or century with the highest peak flows lasting for minutes or hours and reaching on the order 100 times the median annual peak flow. These infrequent, extreme disturbances (including floods, fire, earthquakes, debris flows, etc.) are therefore responsible for maintaining channel form and controlling the removal and recruitment of vegetation. Disturbance events are usually followed by a long "recovery" period which is much slower than would be experienced by a perennial system.

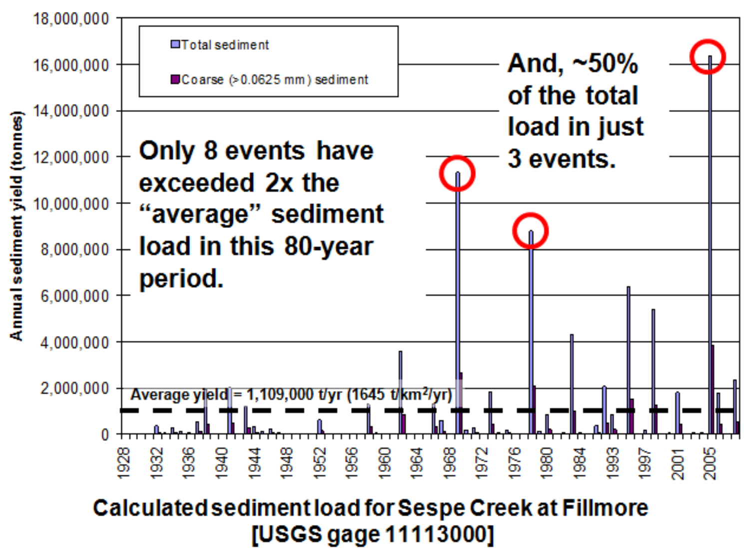

Figure 1

Episodic streams may occur in a variety of setting from mountains to foothills to alluvial valleys. However, they typically occur in one of three general settings (Figure 2). 1) Sand-bed channels supported by flow from local watersheds and short-duration extreme precipitation events; 2) Arroyos in more confined settings where the degradation/aggradation cycle is controlled not only by infrequent high flow events, but also by a complex interaction of hillslope sediment inputs, upstream channel processes, and in-channel vegetation; and 3) Alluvial fans often form at the mouth of canyons where abrupt changes in slope occur in response to geologic conditions that produce differences in topography. The location and form alluvial fan channels can be controlled by either fluvial or debris flow processes, and don't usually exhibit a dominant "disturbance-recovery" cycle. Alluvial fans can occur in less-arid parts of Mediterranean-climate California (such as the Napa or Scott Valleys) and display these same processes.

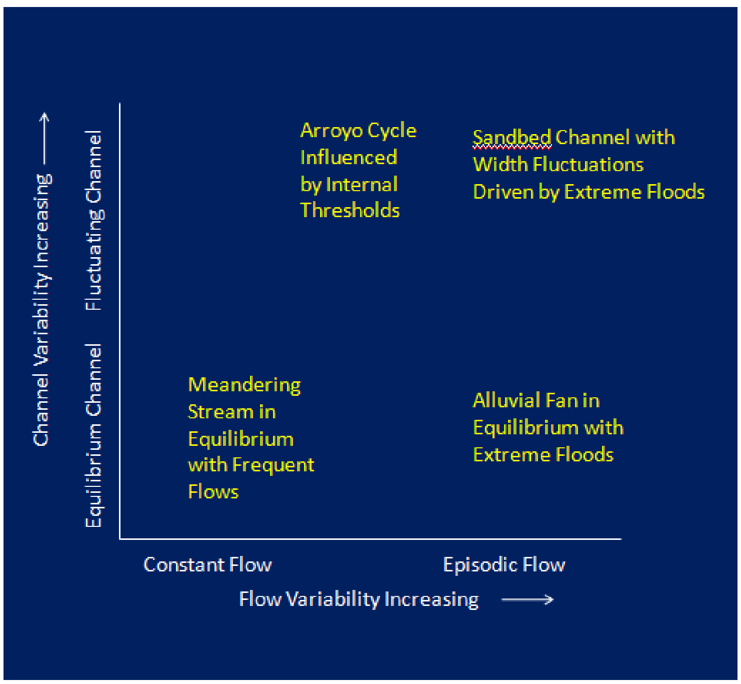

Figure 2

Episodic river systems in arid regions are often intrinsically linked to wind transport dependent ecosystems (Figure 3). These windblown areas are also subject to similar timescales of disturbance as the episodic channel areas, but operate on different climatic time scale (El Nino vs. La Nina climatic events). Episodic stream processes and wind corridor processes interplay through a relationship defined by sediment production in the upper reaches during an El Nino year, temporary storage, and then Aeolian transport during a La Nina year. These episodic stream channels and aeolian corridors link headwaters sediment sources to downwind dunes which are important habitats that support sensitive and listed animal and plant species.

Figure 3

Episodic streams provide numerous ecosystem services including watershed and landscape hydrologic connections, water supply protection and water-quality filtering, wildlife habitat and movement/migration corridors, sediment transport, storage and deposition, groundwater recharge and discharge, vegetation community support, and nutrient cycling and movement. Additionally, these streams form critical interactions with adjacent drier upland areas to support critical life stages and contribute to the overall regional biodiversity. These systems provide primary habitat, predator protection, movement corridors, migration stopover sites, breeding and nesting sites, shade, food sources, and water in temporary or permanent pools for many species. Several state and federal listed species are known to live in these areas, such as California desert tortoise (*Gopherus agassizii*), Coachella Valley fringe-toed lizard (*Uma inornata*), and San Bernardino kangaroo rat (*Dipodomys merriami parvus*). Although many wildlife species are known to be associated with these habitats their distribution and composition are not always well understood or documented.

Threats and Management Challenges

Because demands on the natural resources of the state can result in the elimination of important habitats and fragment and decrease the quality of remaining natural areas, urban growth and development have been identified as a significant threat to species and habitats across the state (CDFG 2007). The dryland regions of California – most notably those in the southern part of the state – are expected to experience increasing population growth and related development pressure over the next several decades (CDFG 2007, Pavlik 2008, AFTF 2010). In addition to increased urbanization pressures, there are currently more than one million acres of renewable energy developments – wind, solar, and geothermal – proposed on public lands in the Mojave and Colorado deserts of California, with another 4 million acres of public lands open for renewable energy project applications. The siting decisions and landscape alterations made for these developments have the potential for lasting impacts on the streams of this environment, the biological communities that depend on these streams, as well as on overall project sustainability and performance.

Development of the dryland regions of California can have numerous and compounding environmental impacts. Nearly all development results in increased groundwater use and surface water diversions that can translate into ecologically detrimental alterations to stream forms and function or to the destruction of a stream system altogether. Development can also impact channels by increasing peak flows through decreased infiltration, or decreased sediment yields from urban landscapes or entrapment in debris basins designed to protect development on alluvial fans against flooding and the impact of debris flows. Development can also increase the frequency of fire which can cause many secondary disturbances like subsequent pulses of sediment for years after the primary event. These impacts are of particular concern because ecosystem recovery in arid and semi-arid environments is significantly slower than in more humid regions.

With the increasing pressure to develop dryland areas it is important to recognize that most traditional assessment tools are based on temperate stream concepts and, therefore, may not be appropriate for use in their current form. These systems pose many unique challenges with regard to their assessment and management not the least of which are the varied and conflicted definitions for "stream" that generally reflect temperate stream concepts not suited to these highly variable episodic stream systems. In a similar fashion, the paucity of classic wetlands or riparian zones and the predominance of xeroriparian ecosystems often results in episodic streams being "undervalued" by common assessment tools based on temperate stream concepts. Moreover, meaningful characterization of episodic stream processes that are highly variable across space and over long periods of time typically demands many more years of study and data collection than their temperate stream counterparts. Thus many of the underlying physical, ecological, and biological processes and interactions of episodic streams remain poorly understood or documented (Levick et al. 2008).

Finally, any analysis of dryland landscapes must be done in tandem with climate change analyses to account for the interaction of long term changes in precipitation patterns on episodic stream channel processes. Most climate models predict severe changes for the southwest US, including increased warming and drying, intensification of droughts and increased variability of precipitation. These changes will result in less runoff, reduced snow packs, changes in stream flow patterns, changes in vegetation growth patterns and changes in wildfire regimes (Levick et al. 2008, Betancourt 2007).

Existing Mapping and Assessment Tools/Approaches

Several agencies and organizations have begun to tackle the mapping, assessment, and management challenges associated with episodic streams. Regarding waters of the state, the California Department of Fish and Game (CDFG) has produced *A Review of Stream Processes and Forms in Dryland Watersheds* (Vyverberg 2010). For federal waters, The US Army Corps of Engineers has produced guidance for determining the Ordinary High Water Mark (OHWM) in arid southwestern channels for purposes of jurisdiction under Section 404 of the Clean Water Act (Lichvar et al. 2006, Field and Lichvar 2007, Lichvar and McColley 2008, Lichvar et al. 2009).

The CDFG guidance provides project siting assistance and mitigation minimization through a system of episodic stream form and process recognition and avoidance incorporated in the site planning and characterization process.

The US Army Corps of Engineers methodology relies on the use of geomorphic signatures including texture changes, vegetation characteristics, and break in slope to determine the limits of arid channels. The Corps documents conclude that although flow indicators and gage data may be useful in helping to identify the floodplain and flow dynamics, flow indicators did not align with recent flood events and are randomly distributed, and recurrence intervals are highly variable. Therefore, a geomorphic signature should be identified and mapped as the primary basis for reliable and repeatable delineations.

Existing tools have the potential to be adapted, modified, or expanded to begin addressing episodic stream function. The Alluvial Fan Task Force (AFTF), established by the California Department of Water Resources, has created a tool to identify and evaluate active portions of alluvial fans based on surficial geologic maps, site assessment, and modeling (AFTF; http://aftf.csusb.edu/). The CDFG Manual of California Vegetation (Sawyer et al. 2009) includes plant alliances that are associated with episodic stream channels. However, given the plasticity of many of these communities and the variability of these systems, alliances can occur along a continuum from upland to in-channel at various points of time. Therefore, vegetation must be used in concert with imagery, mapping of physical features, and an understanding of hydrology. The California Rapid Assessment Method (CRAM; www.cramwetlands.org) includes a module that assesses overall condition of streams based on landscape setting, hydrology, physical features and biological features. In its present form CRAM is not appropriate for application to ephemeral, arid, or episodic streams, but, efforts are underway to adapt CRAM for use in these drier systems.

Recommendations

Following the break out sessions, the participants produced a set of recommendations that, if implemented, would improve our collective ability to assess and manage and conserve episodic streams. The recommendations include both technical/scientific priorities as well as management/coordination priorities:

<u>Technical Recommendations</u>

- Improve condition/function assessment tools to better address episodic streams. Assessment tools should:
  - Account for spatial and temporal variability
  - Account for characteristic patterns and composition of plant communities over time
  - Include and evaluation of connection between stream and surrounding landscape
  - Address appropriate reference conditions over the impact-recovery cycle
  - Be able to discern relict, abandoned, and active features

- Improve modeling capability for episodic systems. This may include deterministic simulation models and/or probabilistic approaches. Both efforts will require additional data collection on temporal and spatial patterns of rainfall, channel form and sediment yield, transport and deposition.

- Pursue research that more clearly relates hydrologic and geomorphic processes to biological condition over all periods of the impact through recovery cycle. Use this understanding to inform:
  - Calibration data for condition/function assessment methods
  - Range of reference conditions over time
  - Trajectories for restoration
  - Monitoring benchmarks

- Develop a coordinated long-term monitoring program that can be shared by among agencies.

<u>Management Recommendations</u>

- Develop science-based terminology and definitions that are shared by all agencies to provide a common foundation for guidance, delineation, and assessment.

- Develop consistent terminology for describing various components of episodic systems. Include a classification system that accounts for hydroclimatic setting, geomorphic setting, and transience of the system (defined as recovery time/time between large "reset" events).

- Establish technical workgroup to facilitate agency coordination and interaction with the scientific community on issues of mapping, assessment, and management.

- Produce better guidance for identifying State jurisdiction in arid system streams and channels.

- Develop consistent stream mapping and classification methodologies to be adopted by management and regulatory agencies.

- Develop formal siting and site-design criteria to minimize effects of development and infrastructure projects on alluvial fans and other episodic systems.

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Appendix A - Workshop Agenda

DAY 1

9:00 – 10:00 – Overview of Episodic Stream Channels (moderator: Eric Stein)

a. Introduction and workshop goals – Eric Stein, Matt Kondolf, and Kris Vyverberg
b. Welcome – Ed Pert, Regional Manager, Department of Fish and Game, South Coast Region
c. Keynote: Physical and ecological processes in episodic channels – Jonathan Friedman

10:00 – 10:20 – Break

10:20 – 11:45 – Geomorphic Forms and Processes (moderator: Eric Stein)

d. Episodic channel hydrology: Long periods of boredom, brief moments of terror – Matt Kondolf
e. Episodic river channel form – Derek Booth
f. Sediment supply and the upland stream connection – Brian Bledsoe
g. Alluvial fans: unique forms and stream process – Jeremy Lancaster

12:00 – 12:30 Panel Discussion: Friedman, Kondolf, Booth, Bledsoe, and Lancaster

12:30 – 1:30 – Lunch

1:30 – 3:00 – Ecology of Episodic Channels (moderator: Betty Fetscher)

h. Ecological and hydrological significance of episodic streams – Lainie Levick
i. Development Pressure of the dryland environment – Ecological implications – Sophie Parker,
j. South of the Spotted Owl: Recurrence, recharge, restoration and resilience – Barry Hecht
k. Intermittent alluvial fan channels in the northern California wine country – Laurel Marcus

3:00 – 3:30 – Panel Discussion: Levick, Parker, Hecht, and Marcus

3:30 – Wrap up of Day 1 and Preview of Day Two; OPTIONAL – Dinner or networking mixer

DAY 2

9:00 – 9:15 – Good Morning

a. Recap of Day 1 and Goals for Day 2
b. Lingering questions, comments, concerns, or discussion items

9:15 – 10:15 – Management Implications (moderator: Eric Berntsen)

c. Development Pressure on the dryland environment – Regulatory and policy implications – Bill Christian
d. Implications of urbanization on alluvial fan – Tom Spittler
e. Large-scale renewable energy project development – Andy Collison
f. Recognition of conservation and management challenges: a first step – Kris Vyverberg

10:15 – 10:45 – Panel discussion: Christian, Vyverberg, Spittler, and Collison

10:45 – 11:00 – Break

11:00 – 12:30 – Challenges of Mapping and Assessment (moderator: Chris Solek)

g. Hydrologic assessment tools for use in episodic channels – Jeremy Lancaster
h. Are you in or out? Challenges of identification and mapping – Katherine Curtis
i. Mapping vegetation defined and controlled by fluvial processes – Todd Keeler-Wolf
j. What does it all mean? Challenges of assessing condition – Eric Stein

12:30 – 2:30 Break-out Groups and boxed lunch

k. Groups 1 and 2 – Recommendations for mapping and assessment – (Physical sciences session chairs: Aaron Allen and Eric Berntsen)
l. Groups 3 and 4 – Recommendations for mapping and assessment – (Biological sciences session chairs: Todd Keeler-Wolf and Deborah Hillyard)

2:30 – 3:30 – Report from Break-out Groups

m. Summary from each group
n. General discussion and conclusion

3:30 – Wrap up, Conclusion, and Next Steps

DAY 3

8:00 – 3:30 – Optional field trip to the Cucamonga Fan complex, East Etiwanda Canyon at the North Etiwanda Preserve, San Bernardino County – Lunch in field

Appendix B – Presenter Biographies

AARON O. ALLEN is the Chief of the North Coast Branch in the Los Angeles District Regulatory Division of the Army Corps of Engineers. His 17-year Corps career has included assignments as a Senior Project Manager and as the Los Angeles District Technical Expert in Dryland Fluvial Geomorphology. The majority of his technical experience has been focused on jurisdictional issues in the arid Southwest, fluvial geomorphology, compensatory mitigation projects, and indirect/cumulative impact analysis. He completed his undergraduate degree at the University of California at Berkeley and MS and PhD at the University of California at Los Angeles. He is also a regular presenter at regional and national conferences on many issues related to wetland regulations.

ERIC BERNTSEN is a staff environmental scientist within the State Water Resources Control Board’s Stormwater Unit. He is a registered professional hydrologist, certified floodplain manager, certified professional in erosion and sediment control, and a certified professional in storm water quality. Eric serves on the executive council of the California-Nevada Chapter of the Soil and Water Conservation Society, the board of the Laguna Creek Watershed Council, and the Sacramento Area Creeks Council. He holds a BA in environmental studies/geology from the University of Pennsylvania and an MS in water resources from the State University of New York. At the State Board, Eric provides technical support in the areas of hydromodification, erosion and sediment control, low impact development, and landscape design.

BRIAN BLEDSOE has 22 years of experience as an engineer and environmental scientist in the private and public sectors. He earned degrees from Georgia Tech, North Carolina State University, and Colorado State University. As Associate Professor and Borland Chair in Hydraulics in the Department of Civil and Environmental Engineering at Colorado State University, his research and teaching are focused on the interface between water resources engineering and river ecology, with an emphasis on linkages among land use, hydrologic processes, sedimentation, channel stability, and water quality. Prior to moving to Colorado in 1997, he served as Nonpoint Source Program Coordinator for the State of North Carolina. He is a licensed professional engineer in NC and CO and has authored over fifty publications related to stream and watershed processes, restoration and water quality

DEREK B. BOOTH is an internationally recognized expert on urban streams and stormwater, particularly the effects of runoff on channel form and function. His first peer-reviewed publication on the subject was in 1989; of his now more than 50 such journal articles and book chapters, more than half are on this topic. He worked for a decade in urban watershed management for King County, Washington, and as director of the Center for Urban Water Resources Management at the University of Washington. He is an Affiliate Full Professor at the University of Washington and a private consultant with Stillwater Sciences. He was a member of the recent National Academy of Science panel reviewing the nationwide NPDES stormwater permitting system.

BILL CHRISTIAN is the Amargosa River Project Director for the California chapter of the Nature Conservancy. For the past 7 years, he has worked to acquire and protect ecologically important Mojave Desert lands, focusing particularly on aquatic and riparian systems. Prior to the Conservancy, Christian spent 30 years as an environmental lawyer, lobbyist, and project manager for the Atlantic Richfield Company, and lawyer for the State of Alaska and the US EPA. He co-teaches an annual environmental law and policy course at Claremont McKenna College.

ANDY COLLISON'S background is in hydrology and geomorphology, with a particular emphasis on channel erosion and restoration issues. Formerly a geomorphology professor at University of London, England, he came to the US for a nine month sabbatical. That was nine years ago, and he is still has not left. After working at the USDA National Sedimentation Laboratory for two years he joined PWA in 2002, where he is now the senior geomorphologist. He led the channel vulnerability portion of the Contra Costa and San Diego Hydromodifcation Management Plans, and has developed instream mitigation for hydromodification in Los Angeles County and the Bay Area.

KATHERINE CURTIS is a research physical scientist at U.S. Army Engineer Research and Development Center (ERDC)/Cold Regions Research and Engineering Laboratory (CRREL) Remote Sensing and Geographic Information Systems (GIS) and Water Resources Branch in Hanover, NH. She received her bachelor's in geology from Colby College and master's in Earth Sciences from Dartmouth College, where her thesis focused on the impact of flow regulation on sediment transport competency. Katie's primary research since joining CRREL 1 1/2 years ago has been on identifying the Ordinary High Water Mark (OHWM) in western streams.

JONATHAN FRIEDMAN is a plant ecologist and fluvial geomorphologist with the US Geological Survey in Boulder, Colorado. He received a BS from MIT, an MS from the University of Wisconsin-Madison and a PhD from the University of Colorado-Boulder. His research addresses interactions among streamflow, channel change and riparian vegetation across the inland western US with emphasis on floods, erosion and invasive plants.

BARRY HECHT is senior geomorphologist and principal at Balance Hydrologics, Berkeley, which conducts hydrologic and geomorphic studies of watershed, channel, groundwater, and wetland dynamics in California and elsewhere, often in support of ecological restoration programs. Mr. Hecht is recognized as an authority on Mediterranean- climate river channels in the California Coast, stream-groundwater interactions, and ecological implications of human-induced changes in these episodic systems.

DEBORAH HILLYARD is a staff environmental scientist with the California Department of Fish and Game, where she is the lead for a number of large scale, long-range conservation planning efforts on the Central Coast of California. Deb's background is in biology and rangeland management, with a particular interest in arid ecosystems, their restoration and management. She has planned and conducted assessment, management and monitoring in diverse ecosystems, including grasslands and shrublands of the Carrizo Plain, dunes and riparian systems in the Anza-Borrego Desert, maritime chaparral of the Central Coast, and coastal sage scrub of the Orange Coast, as well as a number of rare plant inventory, restoration and enhancement projects. Deb approaches her work from the perspective of a community ecologist, with a special affinity for rare natural communities.

TODD KEELER-WOLF is the Senior Vegetation Ecologist at the California Department of Fish and Game and lead's their Vegetation Classification and Mapping Program. Todd has studied and written about vegetation of California for over 30 years and has been involved with sampling, classification, and fine-scale mapping of desert wash and riparian vegetation throughout the state. He is a principle author of the recently published second edition of A Manual of California Vegetation.

G. MATHIAS (MATT) KONDOLF is a fluvial geomorphologist and environmental planner, specializing in environmental river management and restoration, especially Mediterranean-climate and other episodic rivers. As Professor of Environmental Planning at the University of California, Berkeley, he teaches courses in hydrology, river restoration, environmental science, and Mediterranean-climate rivers, along with shortcourses on river restoration taught in the Sierra Nevada of California and in the Rhone Valley of France. He is currently the Clarke Scholar at the Institute for Water Resources of the US Army Corps of Engineers in Washington.

JEREMY LANCASTER is an engineering geologist with the California Geological Survey (Los Angeles), and serves as a technical specialist on flooding and debris flow processes as related to the geomorphology of alluvial fan systems. Recently he served as a technical consultant on the California Alluvial Fan Task Force, and assisted in developing chapters and appendices for the document titled, "The Integrated Approach For Sustainable Development On Alluvial Fans." Mr. Lancaster has published several abstracts on the topic of assessing alluvial fan flood hazards using surficial geologic maps coupled with engineering geologic investigations, and currently has three publications in press/preparation on the same topic.

LAINIE LEVICK is a senior research specialist with the University of Arizona, and works at the USDA-ARS Southwest Watershed Research Center in Tucson, Arizona. She conducts watershed-based research and hydrologic modeling in arid and semi-arid systems in the Southwestern US. She was the lead author on the report "The Ecological and Hydrological

Significance of Ephemeral and Intermittent Streams in the Arid and Semi-Arid American Southwest", which was funded by the EPA Region 9 to support their Clean Water Act jurisdictional analyses in the southwest. Currently she is working on a project to evaluate and classify ephemeral and intermittent stream systems on Department of Defense lands in the southwest region.

LAUREL MARCUS is a restoration ecologist and the executive director of the non-profit California Land Stewardship Institute in Napa. Laurel has worked extensively in the watersheds of northern and central California. Ms. Marcus is the author of the Fish Friendly Farming (FFF) Environmental Certification Program. The FFF program uses collaboration and incentives for recovery of listed salmonid species and water quality improvements on private agricultural and rangeland in 10 watersheds in northern California and the Sierra foothills. As part of implementing stream restoration projects in these areas she has recently focused on alluvial fans and the unique challenge they pose to salmonid migration and native plant revegetation.

SOPHIE PARKER is an Ecoregional Ecologist with The Nature Conservancy and provides science leadership to projects in the south coast and deserts of California. She has worked to ensure the protection of lands and waters along the Amargosa River and in the Coachella Valley, and is one of the authors of the Conservancy's 2010 Mojave Ecoregional Assessment. This document includes science-based information about conservation values, threats, and opportunities within the Mojave Desert that may be used to help inform future conservation and development decisions.

ED PERT is the Regional Manager for the California Department of Fish and Game's South Coast Region. Prior to his current appointment, Ed was the Project Manager for the Department's Lake Davis Pike Eradication Project. Ed was also the Chief of Fisheries Programs Branch after coming to the Dept. as a Fisheries Science Advisor to the Director back in late 2000. Ed was an Assistant Professor in Fisheries at the University of Arkansas at Pine Bluff. When he was actually conducting research his work focused on fisheries, primarily stream ecosystems.

CHRIS SOLEK is a biologist specializing in wetland and riverine assessment and monitoring. He received his B.S. in Wildlife Biology from U.C. Davis in 1992, a M.S. in Biological Sciences from California State Polytechnic University Pomona in 2002, and a Ph.D. in Environmental Science, Policy, and Management from U.C. Berkeley in 2008. He joined SCCWRP in April 2007 and is currently involved with developing and implementing monitoring/assessment programs for southern California wetlands. His current interests include the development of rapid assessment methodologies for arid land streams.

TOM SPITTLER is a senior engineering geologist with the California Geological Survey. In addition to working on geologic hazards associated with timber harvesting and other impacts in northern California, he works on geologic hazard assessments throughout the state, including those related to post-fire debris flow potential. He chaired an Association of Environmental and Engineering Geologists symposium on watershed restoration, has been on numerous California and Federal Emergency Management Agency technical committees evaluating wildfire and earthquake hazards, and was recently a technical consultant to the California Alluvial Fan Task Force where he contributed to three chapters on hazard and resource evaluations of alluvial fans.

ERIC STEIN is currently a principal scientist at the Southern California Coastal Water Research Project (SCCWRP), where he is head of the Biology Department. Dr. Stein oversees a variety of projects related to in-stream and coastal water quality, bioassessment, hydromodification, watershed modeling, and assessment of wetlands and other aquatic resources. His research focuses on effects of human activities on the condition of aquatic ecosystems, and on developing tools to better assess and manage those effects. He is one of the principal authors of the California Rapid Assessment Method (CRAM) and participates in many State and Federal workgroups on approaches to ecosystem assessment. Prior to joining SCCWRP, Dr. Stein spent six years as a Senior Project Manager with the Regulatory Branch of the Los Angeles District Corps of Engineers, and four years with a private consulting firm.

KRIS VYVERBERG is a senior engineering geologist with the California Department of Fish and Game, in which capacity she provides geomorphic and geotechnical expertise to Department staff and other State and Federal resource management agencies with whom she works to protect and restore the waters of the state. She is the principal technical consultant to Department's Lake and Stream Alteration Program on stream delineation issues, the geological and geomorphic considerations of watershed management and restoration projects, and the environmental compatibility of projects in the stream corridor.

Appendix C - Detailed Presentation Summaries

Episodic Stream Workshop Presentation Summaries

Complete presentations available at:
ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/645_EpisodicStreamWorkshopPresentations/

Workshop held at
Southern California Coastal Water Research Project

November 8 – November 9, 2010

Contents

Episodic Stream Channels: Geomorphic Forms and Processes

November 8, 2010

Hydrology, Form, Sediment Supply, and Alluvial Fans **is a compilation of the following presentations:**

Jonathan Friedman

Physical and Ecological Processes in Episodic Channels

[Presentation]

G. Matt Kondolf, University of California Berkeley

Episodic Channel Hydrology: Long Periods of Boredom, Brief Moments of Terror

[Presentation]

Derek Booth, Stillwater Sciences

Episodic Channel Form - the Biggest Flood of Record Creates the Form of the River

[Presentation]

Brian Bledsoe, Department of Civil and Environmental Engineering, Colorado State University

Sediment Supply and the Upland-Stream Connection

[Presentation]

Jeremy Lancaster, California Geological Society

Alluvial Fans - Unique Process and Forms

[Presentation]

Hydrology, Form, Sediment Supply, and Alluvial Fans

1) Episodic Rivers are different:

One of the first "problems" of episodic rivers is our perception of them. The majority of hydrologists, geomorphologists, and river restoration practitioners have been trained in humid climates, or snowmelt-dominated regions, and many of the field's seminal papers present research conducted in those areas. Thus, among scholars and practitioners alike there is often a subtle bias towards viewing all rivers with the tools and concepts that were developed and intended only for humid or snowmelt systems. Our cultural preference for perennial streams may be even more deeply rooted as demonstrated by the term "wasteland" have been used for arid regions. In practice, these subtle biases may inspire "restoration" projects in sites with no genuine problem to be solved. For example in Uvas Creek, California "restoration" was implemented to force the wide and braided channel into a narrow, single-thread channel. After a more thorough historical analysis, however, the braided planform was actually deemed appropriate for the system. Not surprisingly, the narrowed channel returned to the wide and braided condition following a moderate flood shortly after the narrow channel was constructed. Improved evaluation methods for episodic rivers is essential to ensure that proposed restoration projects are beneficial and to decrease the likelihood that projects will fail following construction.

Episodic rivers often do not have stable channel forms or consistent relationships between flood frequency and geomorphic bankfull conditions. In snowmelt systems bankfull discharge is commonly associated with the ~1.5-year recurrence interval discharge and with the effective discharge (the flow that over time transports the most sediment) . These associations are not appropriate in episodic systems where 1) there may not even be identifiable geomorphic indicators of "bankfull" and 2) the effective discharge is likely an infrequently recurring event . Instead, episodic river channels should be understood to be periodically "reset" by infrequent disturbance (including floods, fire induced sedimentation, debris flows) and then in periods of "recovery" in which channel narrowing may occur and hillslope sediment inputs and instream sediment transport are low. Restoration projects should therefore be careful not to inappropriately seek a stable channel in these systems. Restoration in episodic systems should prioritize restoring and/or maintaining processes such as sediment continuity from hillslopes and down the channel, and minimizing hydrologic alteration.

Fundamentally there is no distinct demarcation of episodic rivers. Rather, there is a spectrum of rivers of varying rates of channel change, sediment transport, and hydrologic variability. Rivers may exhibit extreme variation in inter-annual flow or intra-annual flow, while others may primarily vary through geomorphic processes such as cycles of channel widening and narrowing or aggradation and degradation. Site-specific analysis of processes, forms, and long-term range of variability is recommended.

<u>Setting and context of episodic rivers</u>

Episodic rivers occur in regions with unique geologic, climatic, and ecologic processes. Understanding the current and historical influence of these processes on hydrology and sediment transport is an essential tool for evaluating episodic rivers. In particular, the tectonic setting (rate of uplift), rock types (and the associated weathering rates), and climate (the intensity or precipitation is more important than total annual precipitation) control sediment production. Surprisingly, the maximum recorded rainfall intensity at intervals of 10 to 100 years is greater in portions of the San Gabriel and San Bernardino Mountains of southern California than anywhere else in the continental United States (Western Regional Climate Center http://www.wrcc.dri.edu/). Furthermore, in forested watersheds, total annual precipitation is negatively correlated with sediment yields because precipitation enhances vegetation which leads to increased soil stability [*Knighton*, 1998; *Langbein and Schumm*, 1958]. Episodic rivers are therefore highly dynamic systems because they are concentrated in areas with 1) high uplift rates, 2) erodible rocks, 3) high-intensity precipitation, and 4) little vegetation to induce soil stability.

When evaluating the setting and context of episodic rivers it is also essential to consider the land use impacts from present and historical activities. These ongoing processes and the legacy impacts of historical events can shape both the channel form and alter hillslope processes related to vegetation, sediment production, and fire regime. In the Santa Clara River, the timing of and interaction between flow regulation, channel modifications, mining, agriculture, ranching, and urbanization influence the processes and forms of the present system.

Fire frequency and intensity dramatically influence post-fire vegetative recovery and erosion. Fire therefore plays an especially important role on hillslope processes where sediment yield following a fire can be several orders of magnitude higher than pre-fire rates (See Barry Hecht presentation). Additionally, if fire (or another process) removes streambank vegetation, then the rates of channel migration, widening, or avulsion, may also increase.

2) Flow

Intra-annual variability

Peak flows in humid climate, spring-fed, or snowmelt driven systems such as the Yellowstone River in Montana may exhibit only moderate variation throughout the year. For example, peak flows on the Yellowstone River are on the order of 20 times the baseflow discharge. By contrast, episodic systems such as Kiowa Creek, Colorado may flow only a few times per decade or century . In episodic systems, the infrequent events are therefore responsible for maintaining channel form and controlling the removal and recruitment of vegetation.

Inter-annual variability

The highest peak flows from long-term gauge records from snowmelt systems such as the Yellowstone River may be on the order of only 2 times the median annual peak flow. By contrast, in episodic systems, the highest peak flows may be on the order 1000 times the median annual peak.

Duration of peak flows

Peak flows in snowmelt dominated watersheds such as the Yellowstone River typically last for months. By contrast, episodic systems are categorized by flashy peaks that may only last for minutes or hours. Because large watersheds aggregate the precipitation and travel times of flow, the flashiest peak flow events typically occur in small watersheds where runoff can be nearly instantaneous.

3) Human alteration

Mediterranean regions are densely populated and land-use alteration is frequently intensive. Additionally, limited annual precipitation, the need for irrigation, and dry summers make Mediterranean rivers some of the most heavily altered in the world. Also, the capacity of reservoir storage in Mediterranean regions is often very high relative to the total annual runoff. Reservoir storage in Mediterranean regions is on the order of 60-120% of annual runoff. In humid climates reservoir storage is typically only 5-20% of annual runoff.

4) Sediment Inputs and Sediment Transport

The river system can be considered in 3 parts: 1) the headwaters where sediment is generated, hillslopes are highly connected to channels, and channels are steep; 2) the transfer zone where sediment is generally passed through or stored temporarily in flood plains, hillslopes are less connected to the channels, and channel slopes are gentle; and 3) the depositional zone where sediment is deposited in low gradient areas.

A gradient of sediment transport processes and grain sizes also exists along the river profile. In headwaters regions sediment particles are larger, and a substantial portion of total sediment transport is moved as bedload. In lower regions the finer sediments are predominantly transported in suspension. Hillslope sources of sediment include creep, rainsplash, sheetwash, rilling, gullying, landslides, and debris flows. In steep and dynamic episodic systems, landslides are responsible for a large portion of sediment delivered to the river.

The sediment supply is also heavily influenced by both fire and climate. In general, El Nino years typically have much higher sediment yields due to the increased likelihood of storm events. Similarly, post-fire years transport more sediment because of the absence of vegetative stability of the soil. Extreme sediment transport can occur if large storm events occur during post-fire years. For example, in the Santa Clara River over a 40 year period the majority of sediment transport occurred during a single event. In summary, episodic rivers of Southern California are characterized by high sediment yields because of 1) high frequency of fire; 2) high intensity precipitation; 3) rapid rates of tectonic uplift; 4) weatherable rocks; and 5) low soil stability provided by vegetation. For example, sediment production in Southern California's Santa Paula Creek is even higher than published studies for deforested watersheds of the Pacific Northwest.

5) Channel Form

Episodic rivers are dynamic systems with active channels. Avulsion and channel migration should therefore be expected and planned for. For example, Sespe Creek channel migration was mapped showing substantial movement within seventy years. Episodic systems exhibit great variability in channel forms both spatially (different reaches of the same river) as well as temporally (the same location at different times). Plum Creek in Colorado and the Carmel River in California are examples of rivers that undergo periodic widening (in response to flood events) and subsequent narrowing and revegetation. Many riparian species in arid and semi-arid regions are reliant upon this dynamic widening and narrowing cycle for establishment.

Channel form and dimensions are controlled by inflowing water and sediment. Secondary controls include cohesiveness of bank material, and channel stabilizing vegetation. The classic channel evolution models of Schumm (and later Simon) are often useful in describing the self-correcting mechanisms of channels that lead to natural recovery of "quasi-equilibrium" in incising systems . Schumm describes a 6-stage process of incision and widening that ends with an active flood plain and reduced rates of bed and bank erosion. However, recent work by Hawley et al. (in prep) suggests that perturbed Southern California streams may actually evolve towards a variety of quasi-equilibrium forms that may not resemble the pre-disturbance forms. This suggests that persistent impacts to flow and especially to sediment inputs can be responsible for irreversible channel change.

Lane's Balance offers a conceptual model for understanding how perturbations to flow or sediment inputs will impact channel form. Specifically, Lane's Balance illustrates how degradation can be caused by 1) increased flow; 2) decreased sediment yield; 3) decreased sediment size; and 4) increased slope. Development can impact channels by 1) increasing peak flows through decreased infiltration (a commonly recognized problem), but also through 2) decreased sediment yields from urban landscapes, or trapping of sediment through detention ponds meant to mitigate the hydrologic alteration; and in particular, 3) structures that prevent coarse sediment from being transported downstream. Channel sensitivity to perturbation should therefore be evaluated carefully. The ratio of disturbing to resisting forces can provide useful insight and identify systems that are close to a threshold such as incision. Fundamentally, maintaining the supply and transport continuity of course sediment is essential to prevent crossing geomorphic thresholds.

<u>Arroyos</u>

Arroyos are a specific type of episodic system that go through pronounced cycles of aggradation and degradation. The aggradation-degradation cycle is controlled not only by infrequent high flow events, but also by a complex interaction of hillslope sediment inputs, upstream channel processes, and in-channel vegetation. Essentially, if erosive forces (flow) exceed resisting forces (sediment supply, bed/bank cohesion- aided by vegetation), then the channel will incise. If the channel widens (reducing stream power), vegetation becomes established or high sediment loads exceed the transport capacity, then aggradation will occur. An example of these dynamics from the Rio Puerco, New Mexico showed that bank failure and channel widening during a high flow event occurred only in reaches where the riparian vegetation (*Tamarix*) had been removed.

Alluvial Fans-

Alluvial fans can be considered episodic systems because of the inherent variability in flow. However, channel forms can be stable over centuries or millennia in some fans. For example, the distributary network of the Wild Burro Fan in Arizona can be considered geomorphically stable because even infrequent high-flow events do not cause substantive channel erosion.

Other alluvial fans are more active. However, even in the more dynamic fans, some segments are typically stable over long periods. Segmented fans reflect changes in climate and geologic regime and different portions of fans may be stable over varying periods. Thus, some portions of a fan are much better suited for development. In arid regions, the development of desert varnish can be used to highlight segments that have been stable over long periods.

Furthermore, when assessing the dynamism of alluvial fans it is useful to distinguish fans dominated by debris flows (active) from fans dominated by streamflow (less active).

Debris Flow Fans

- Dominated by hyper-concentrated flows and debris flows
- Sediment and debris concentrations approx. >20%
- Steep slopes approx. >7%.
- Boulder-lined levees, terminal snouts, boulder fields, and trapezoidal channels.
- Deposition is episodic, and flows easily overtax fluvial channels.
- Avulsion at the fan apex is likely during large flows.

Stream Flow Fans

- Dominated by water floods
- Sediment concentrations of approx. <20%
- Slopes flatter than 7%.
- Channels are braided
- Channels migrate

- Channels have high width to depth ratios.
- Whole fans may be characterized by actively migrating flow paths or by active abandoned and relict depositional surfaces

Ecology of Episodic Channels

November 8, 2010

Lainie Levick, University of Arizona
Ecological and Hydrological Significance of Episodic Streams

Sophie Parker, the Nature Conservancy
Development Pressure of the Dryland Environment: Ecological Implications

Barry Hecht, Balance Hydrologics
South of the Spotted Owl, Revisited: Recurrence, Recharge, Restoration and Resilience

Laurel Marcus, California Land Stewardship Institute
Intermittent Alluvial Fan Channels in the California Wine Country

Ecological and Hydrological Significance of Episodic Streams

Lainie Levick - *University of Arizona*

[**Presentation**]

The majority of streams in the Southwest, Nevada, and California are not perennial.

Percent of streams that are ephemeral or intermittent

Arizona	94%
Nevada	89%
New Mexico	88%
Utah	79%
Colorado	68%
California	66%

These streams function differently than perennial streams but provide the same ecosystem services including: watershed and landscape hydrologic connections, water supply protection and water-quality filtering, wildlife habitat and movement/migration corridors, sediment transport, storage and deposition, groundwater recharge and discharge, vegetation community support, and nutrient cycling and movement. Additionally, these streams support high biodiversity relative to their associated dryer uplands.

There is a relative lack of ecological data for ephemeral and intermittent streams and therefore a lack of understanding and mapping of their biodiversity. A historical focus on perennial systems as preferable, high quality habitat has led to ephemeral and intermittent streams to often be characterized as "degraded" and the habitat they provide has been undervalued. However, the health of the entire watershed depends on the health of all its stream reaches.

Vegetation in and along episodic streams can be denser and more diverse in comparison to surrounding uplands, providing many important functions. The vegetation around these streams serves numerous physical functions like protecting soil from wind and water erosion and moderating the water and air temperatures. It provides channel and stream bank roughness, influencing flow velocities, flow depths, and sediment transport and deposition. It contributes to channel features by stabilizing sand bars, and initiating formation of other depositional features (bars, benches, ridges or islands). The vegetation along these channels also provides important ecological services. It influences biogeochemical cycles and the water/energy balance and provides food and cover for wildlife.

Many wildlife species are known to be associated with these habitats but their distribution and composition is not well understood or documented. Dryland species have developed many special adaptations to the water-limited conditions including: heat evasion (daily or seasonal estivation, diurnal or nocturnal behavior), water conservation strategies, water storage strategies, dehydration tolerance, heat tolerance, heat dissipation, and very rapid development from egg to young. It is known that these systems provide primary habitat, predator protection, movement corridors and migration stopover sites, breeding and nesting sites, shade, food sources, and water in temporary or permanent pools for these species. The majority of benthic macroinvertebrates occur in ephemeral or intermittent streams. Reptiles and amphibians rely heavily on dry washes for breeding and food and large mammals use dry washes for cover, shade, forage, nesting and breeding. Avian species are highly dependent on riparian corridors whether perennial, intermittent or ephemeral.
Ephemeral and intermittent streams constitute the vast majority of drainage ways in the Southwest and perform the same ecosystem services as perennial streams. However, more research is needed on the *ecological and hydrological interactions* in dryland streams.

Currently, Levick and others at the University of Arizona and ARS/SWRC are working to complete a project entitled: "An Ecohydrological Approach to Managing Intermittent and Ephemeral Streams on Department of Defense Lands in the Southwestern United States." This four year project, funded by the Strategic Environmental Research and Development Program (SERDP) of the Department of Defense has the following objectives:

- to develop an Ecohydrologically-based Classification for ephemeral and intermittent stream types based on hydrologic, geomorphic, and vegetative attributes and
- to assess the impacts of perturbations (e.g. climate change, military activities) on the hydrologic regimes and habitats of these systems, and the threatened, endangered and at-risk species that depend on them and to improve management decisions.

The study assumes the hydrologic and geomorphic characteristics of the stream influences the riparian vegetation communities, which determine habitat types and values that support TER-S. The study used the following methods:

- Riparian and Upland Vegetation and Geomorphic Field data collection
- GIS/RS analysis of vegetation and geomorphology
- Hydrologic modeling for flow permanence and extent
- Data evaluation and classification of stream "types"
- Identification of species of concern and their habitat requirements
- Identification of linkages between stream types and species habitat needs
- Assessment of climate change and land use impacts on stream types & habitats

To date project investigators have conducted field trips to all study sites (Ft. Bliss, TX, Ft. Irwin, CA, Ft. Huachuca, AZ, and Yuma Proving Ground, AZ. Preliminary observations have been made regarding stream "type" variability related to geology, soils, topography, position on the landscape, and climate. Thus far it has been found that "riparian vegetation" may be absent, only slightly different from uplands, or only in the channel. Frequently, no typical riparian vegetation zone is readily discernable. At this date it can be concluded that much of the usual riparian vegetation and geomorphic terminology and concepts don't quite fit these systems.

Development Pressure of the Dryland Environment: Ecological Implications

Sophie Parker - *The Nature Conservancy*

[**Presentation**]

Mojave Desert Ecoregion Assessment available online at:
http://conserveonline.org/workspaces/mojave/documents/mojave-desert-ecoregional-2010/@@view.html

With the increasing pressure to develop dryland areas it is important that the implications of development pressure of dryland systems are better understood. This includes the specific types of development pressure that are changing the desert environment and how these changes can have consequences for natural systems. Development pressure can be defined as: "Human alteration of landforms from a natural or semi-natural state for a purpose such as housing, industrial use, or agriculture." Within this definition are nested various types of development: housing and commercial structures, electricity generation, transmission lines and utility corridors, mining, agriculture, and transportation infrastructure that accompany the building of cities and towns. Nearly all development requires groundwater pumping, water diversions, or streambed modifications.

For Example, in the Mojave Desert Ecoregion, together, housing and commercial development and mining constitute two of the major types of development that have occurred in the Mojave Desert thus far. Mining has been largely focused on more mountainous areas, whereas urban development has occurred in flatter areas and on the alluvial fans north of the transverse ranges. Agriculture is another type of development which is important in arid lands. There are two types of development which are likely to exert the most pressure on natural systems in the Mojave Desert in coming years: urban expansion and electricity generation and transmission.

The majority of the land within the Mojave and Sonoran Desert Ecoregions is comprised of areas that potentially contain alluvial fans. Without recognition of the nature of episodic water flow in these systems, developments are at a huge flooding risk. Development of alluvial fans is not new, but in the future it will become more the norm than ever before. Up to 60% of the new development in southern California in the 21st century will occur on alluvial fans.

Both dense urban development and more scattered, rural housing development have taken place over the past several decades in the Mojave Desert at a pace that is unprecedented, including a huge increase in rural residential development in the west, which is now starting to fill in and become denser and more urban. Electrical generation facilities and transmission lines is evidently a new wave of large-scale industrialization underway in the Mojave Desert. Proposed electricity generation facilities and transmission lines in the Mojave Desert demonstrate a pattern of development of solar along flatter areas and alluvial fans, and wind on ridgetops.

The Daggett Solar Power Facility in the Mojave Desert and the Brightsource Solar Power Facility in Israel are examples of these types of facilities. At facilities such as these, thousands of computer-controlled flat mirrors called "heliostats" focus the sun's rays onto a central power tower. In this tower a boiler creates steam to turn a turbine which generates electricity. To build these large facilities the ground is typically cleared prior to installation.

The Brightsource power plant, currently being built in the Ivanpah Valley in the Mojave Desert near the CA/Nevada border, is an example of a large facility within an alluvial plain. This facility will boast 459-foot-tall towers and 347,000 heliostat mirrors on 4,000 acres (6.25 square miles). The towers will be as tall as Los Angeles city hall building and the footprint of the installation is 10 times the size of the Disneyland Resort in Anaheim. This facility broke ground in October, and it is the first of several solar power plants that have been "fast-tracked" to allow for their rapid construction in the California desert. The site is located in an area of intact desert scrub. This area includes numerous rare plants and threatened desert tortoises and is adjacent to the northeast corner of the Mojave National Preserve.

In addition to solar power, desert and arid lands are currently being developed for wind energy which typically takes place in passes, along ridgetops, and in other locations that are windy. Many of these locations, including the Tehachapi Mountains area, are also important corridors for migrating bird species which can be harmed by the wind turbines. Ecological and physical implications of renewable facilities development are not considered as important for the siting of projects as the transmission lines and associated roads are as this infrastructure will transport the electricity generated by far-flung wind and solar facilities.

There are a wide variety of environmental changes that occur when development takes place. These include the following, and each development project will vary in the severity of each type of environmental change:

- clearing of native vegetation, grading of site, scraping of soils
- leveling and paving for transportation infrastructure: roads, rail, and airports
- excavation and earth moving
- building of structures: buildings, towers, windmills, utility lines
- water diversions and streambed modifications
- water use
- introduction of non-native species (including crops and livestock)
- irrigation
- noise and vibrations
- light
- heat island effects
- edge effects: recreation, disposal, etc.

A variety of ecological processes are disrupted by development and important disturbance regimes can be altered. For instance, there are many areas where biological crusts form the living floor of the desert, holding soil particles together. Soils in arid landscapes can be incredibly fragile and development can disrupt soil genesis and integrity, carbon cycling and sequestration, and nutrient cycling. Development can reduce or otherwise impact groundwater resources, can impede sand and sediment transport and pollen dispersal by wind, and can increase the frequency of fire. These impacts are particularly concerning because recovery in these environments is slower than in more humid regions. For example, plants adapted to this environment are often long-lived and slow-growing. Additionally, many of the processes are difficult to map as they are dynamic in space and time and cross mapping unit boundaries

Surface water is rare in arid environments. In the Mojave Desert, there are only a handful of rivers that flow year-round, and these all have portions of their length that usually run dry. In this area, TNC-acquired land along the Armargosa River provides habitat for a variety of wetland associated species, including migratory birds.

Development is seriously threatening water resources in the desert due to overdraft. This is caused by pumping of groundwater for various purposes, including urban development, construction, electricity generation, and agriculture. Overdraft leads to the lowering of the groundwater table, reduced availability of water at natural springs, and loss of habitat for aquatic and riparian species. This has in many places necessitated the building of more human-managed water sources for wildlife. If too much groundwater pumping occurs, infrastructure such as guzzlers can be built to accommodate some wildlife such as bighorn sheep, but these sources of water do not provide the full suite of benefits to species that a natural spring would.

There are various forms of pollution that result from development as well. Nitrogen deposition is one important type that occurs due to vehicle emissions and has been found to promote the grass-fire cycle. Airborne toxicants can lead to disease and death in sensitive species, light from urban areas and industrial facilities are problematic for species that have adapted to be active in the nighttime, and noise and vibrations are problematic for species that have developed sensitive hearing (McGinn and Faddis 1997).

All species (rare or common, listed or unprotected) have habitat requirements, and few of these are compatible with the environmental changes that take place as a result of development. Core habitat destruction due to development is of major concern. For instance, the state-listed Mohave Ground Squirrel, found in the western portion of the ecoregion, provides an excellent example of how habitat destruction can lead to the decline of species. Its limited range makes it vulnerable to extinction. Invasion by non-native species or facilitation of predators such as coyotes and ravens can also have direct impact on sensitive species. In addition to core habitat destruction and the introduction of invasive species, development can fragment and degrade habitats leading to "death by a thousand cuts" scenarios for species. Though they may be directly protected, their existing habitats are too small or somehow compromised in ways that are detrimental to their long-term survival. For example, fragmentation prevents wildlife movement between patches of otherwise suitable habitat. The interruption of wildlife movement can be caused in washes by streambed modification and across landscapes by large developments. Roads and fencing create linkage issues over the land through fencing and direct strikes on roads. Wind and solar facilities can also impede movement through the air, negatively impacting bird, bat, and insect populations.

As the Mojave Desert becomes ever more fragmented, planning is underway to describe the important wildlife linkage areas throughout the region that will provide the connectivity necessary to allow for wildlife movement, long-term gene flow, and migration. This map was a product of the Missing Linkages conference held by South Coast Wildlands, The Nature Conservancy, and other partners in San Diego in 2001. Each of the pink linkages shown in the desert is under further investigation.

Arid regions are being developed at an unprecedented level recently which poses complex problems that need to be investigated and addressed. What makes arid systems unique? It can be demonstrated through the "six P's": precipitation, present threat, pace, political pressure, public ownership, and preciousness. Due to their low annual precipitation, arid lands are often portrayed as wasteland with little to no value other than for development. Mesic systems in the U.S. have been impacted for centuries and so conservation and restoration solutions began to be developed early on. Arid lands are facing a new present threat, having only recently come under major development pressure, and so fewer tools have been developed to protect these unique environments. This development is happening at a rapid pace that is further intensified by political pressure due to a desire for a "win-win-win" solution for climate change, job creation, and investment in new technologies. California Governor Arnold Schwarzenegger was recently quoted saying, "Some people look out into the desert and see miles and miles of emptiness. I see miles and miles of gold mine." The majority of arid lands are publically owned and therefore the traditional conservation approach of buying the property to protect it won't work. Conservation in arid lands needs to be approached through management efforts that involve many partners and encourage discussions on how we use public lands. Arid lands constitute the last great wilderness in North America and arid systems are fragile and slow to recover from disturbance. For this reason alone they should be considered a precious resource.

Because the desert is so unique with regard to development pressure, The Nature Conservancy recently completed an assessment of the ecoregion's conservation value (please visit www.conserveonline.org. for a more comprehensive summary of the analysis that was used to characterize the spatial distribution of conservation value in the Mojave Desert). This assessment provides background on the threats posed to conservation targets by various types of development in the Mojave Desert, presents a vision for protection and management that will ensure the long-term viability of the conservation value of the ecoregion, and provides strategies for doing so. Mojave Desert Ecoregion Assessment available online at: http://conserveonline.org/workspaces/mojave/documents/mojave-desert-ecoregional-2010/@@view.html

South of the Spotted Owl, Revisited: Recurrence, Recharge, Restoration and Resilience

Barry Hecht - *Balance Hydrologics*

[**Presentation**]

An episodic corridor is one where the substrate is renewed, rejuvenated or 'reset' abruptly, at intervals shorter than those typically needed for a mature woodland or streamside community to develop.

Systems with channels that stay in a chronic range have historically been the major scientific and management focus. Rarely are these systems dependent on extreme events. Episodic systems are not as well studied but support communities that do not depend on a mature, climax, serial state like the temperate region streams we are used to looking at.

In these systems the upper portion of watershed dictates sediment transport for the entire length of the channel. Confluences, landslides, springs, and bedrock controls more heavily influence transport then other areas. Extreme events in episodic systems can last everywhere from minutes to days. Additionally, primary episodes beget secondary episodes; system will often experience secondary events that stem from the first perturbation for years to come. These secondary events are often short and long term pulses of sediment. Fire is the ultimate disturbances in these systems, creating compound episodes where sediment pulses vary over time. Corralitos Creek hazard rating for episodes demonstrates this.

Sediment accumulation in Los Padres reservoir demonstrates that when sediment is sampled during chronic periods we are missing half the story. Episodes can be up to half the load.

The Arroyos Seco and San Lorenzo average summer base flows show a constant relationship between the two rivers until the 1977 fire. After 1977, the burned watershed became extremely sedimented and burned vegetation had undeveloped root systems that were not accessing the groundwater and therefore caused flow to increase to 3-4 times the chronic flow. The increased influx of sediment (for example, a local gage showed 9-10 feet of sand) is bad for fish, however, summer flows were at the post fire premium making more water available to help them survive.

Fires can create a relatively predictable sequence in which pools and riffles fill, riparian vegetation get wet feet and die, banks begin to erode, and the canopy opens as willow replaces alders. Finally, a fundamental change in sedimentation is caused by large woody debris.

Fires seem to cause variability in the type of sediment pulses over different time periods, usually over years. An initial pulse of ash and gunk is followed by silt, clay, and, sand. There is then a subsequent pulse of gravel.

Pulse response can be measured; however, cause and effect assumptions cannot be made as these pulses do not occur in every case. For this reason pulse probability should be investigated following fire disturbances. The important questions we need to examine include:

1. Can we predict and measure them?
2. Can we measure and track them?

Episodes are an integral and often a non-segregable part of the California landscape. Planning with episodic analysis has a quantitative scientific basis and has an important role in environmental management and planning. Perhaps they are best incorporated as a parallel paradigm with primary episodes and a range of derivative or delayed results identified and anticipated. Episodic planning for arid, alpine, arctic, or dune landscapes can draw upon what is known from the semi-arid environments.

An Episodic Analysis can be defined as an analysis of events which fundamentally change the functions and morphology of a channel in response to a watershed event, with attenuation/recovery over a finite period of years (relative to salmonid generations, riparian succession, or other management goals) and including derivative or subsequent processes. Examples of primary events include: major storms, fires, landslides, drought, earthquakes, cutoffs and avulsions, and windstorms. Here is a sample of an episodic analysis:

- Known event history
- Current conditions and their episodic status
- Evaluation of primary episodes, and their likely recurrences
- Description of expected secondary derivative and subsequent episodes and process

- Their likely effects
- What may not be known
- Implications for climatic change

There are several regulatory applications for this type of analysis:

- Watershed plans of various types
- Biological Assessments and Biological Opinions
- Major EIRs, EISs,
- Functional Equivalents, FERC and Water-rights permits
- HCPs and RWQCB Basin Plans
- Fiscal plans (capital improvement; and bonding)
- General Planning process
- General plans
- Specific plans
- Plan elements, e.g.:
  - Natural hazards or fire management
  - Conservation and open space
  - Aggregate-resource, and
  - Beach-sand supply plans

There are linkages between episodic and climate-change analyses therefore we must do these analyses in tandem with climate change analysis:

> "Climate change projections also include fluctuations in temperature, the potential for more frequent periods of drought, and the likelihood of intense storm events happening more

often. These changes are likely to have an impact on riparian vegetation composition and density, as well as the frequency and erosive power of high flow events."

--*County of Marin, Miller Creek Existing Conditions Report, 2008*

Intermittent Alluvial Fan Channels in the California Wine Country

Laurel Marcus - *California Land Stewardship Institute*

[**Presentation**]

The Napa and Russian River basins in Northern California are both distinctive due to their alluvial fan features and their large alluvial valleys laced with faults. They don't look like desert alluvial fans because they are covered by vegetation and farmland. Both these watersheds support steelhead trout and several species of salmon as well as high quality wine grapes and numerous wineries. Unfortunately, both the Napa River and Russian River channels have entrenched into their alluvial floodplains impacting stream flow and subsequent fragmentation of important migration corridors. Due to this, water rights and restoration issues are now driven by salmonid species.

The Napa Valley is an alluvial basin dominated by vineyards. In this valley, fans are found where streams come out of the mountains pushing the mainstem Napa River back and forth across the valley. In Napa it is difficult to distinguish fans due to farm land, oak woodlands, and other vegetation. However, different areas along tributary creeks support different needs for fish and are important for how the fish can move in and out of these systems.

The Napa Valley supports some of the most valuable farm land in the world particularly due to the alluvial fans. After large storm events the streams would fill the head of the alluvial fan with sediment. To control the migration of the channel across the fan surface, which can damage vineyards, farmers would dredge the channel out after large events and pile the excess sediment on the banks. These management actions changed the conditions in the streams for salmonid migration providing regular open access when formerly the fish only had access during high flows. Due to this practice sediment has not been allowed to reach the mainstem Napa River. Additionally, the river has been restricted from meandering into the fans to gain sediment. This is one of the main reasons this river is being starved of sediment and is entrenching. The entrenchment of the river has lowered the water table enough to cause the tributary streams to become dry sooner in the year and stay dry longer. The drying of these channels has effectively cut off migration corridors and the lack of suitable gravels is also impacting salmon spawning habitat in the river.

In the Napa region there have been several past restoration efforts. Selby Creek Restoration Project is one example. The project boundaries include where the creek exits the canyon to where it meets the river. The project proposal was to build rock barb to create a self maintaining channel and anadromous fish rearing habitat.

In Napa, the local resource agencies don't understand these dry, intermittent stream systems. They attempt to restore them as if they were meandering valley streams like the mainstem river. The Selby Creek project, however, is located in a dry area supporting upland vegetation and, although there are historical accounts that there was once water here before the river became entrenched and lowered the water table, it is doubtful that this area will support anything but fish passage.

There is a need to provide access for fish up into alluvial fan streams and headwaters and to provide sediment to the mainstem river. For this reason there are now proposals to move the piles of dredged gravel to the mainstem manually. The study for these proposals will be done in a year (2011-2012).

The Russian River has similar geology to the Napa and is also great wine country because it is so dry. However, it is larger than the Napa and has a series of valleys and a large reservoir. Lake Mendocino has cut of sediment from the Russian causing it to become entrenched 15-20 and subsequently lowering the water table.

Morrison Creek is a tributary to the Russian. It has little vegetation except at the upper reaches because the flow drains onto alluvial deposits and quickly infiltrates due to the entrenchment of the Russian. At low flow in the river channel water exiting the creek canyon onto the alluvial valley will percolate into the alluvium until the alluvium is filled with water and the river rises. The slope of the ground water basin between the creek outlet and the river level determines how quickly the water percolates. This disconnected flow cuts off outmigrating salmonid juveniles born in the upper reaches from reaching the main stem. Often a small spring or fall storm will bring out the fish and cause stranding because there is no connected flow. In the spring how do we get continuous flow from the canyon to the river to provide for outmigrating salmonids?

A restoration project in the Redwood Creek drainage of the Russian River watershed is another example of how local resource agencies attempt to restore streams but do not understand the processes that drive them. Redwood Creek has great steelhead habitat in the upper reaches but experiences the typical disconnection issues in the alluvial fan valley. The restoration project included cross channel weirs to change the stream hydraulics to form pools. A flood in 2006 buried the weirs in bedload.

A new project intends to create a self maintaining channel, riparian corridor, and a rock ramp at a stream crossing where there is currently a passage barrier, although it is not clear how it differs from the previous design. The California Land Stewardship Institute will monitor the project and analyze this and 5 other alluvial fan channels to develop improved protocols for agency staff to recognize these channels as well as provide recommendations for restoration practices. Monitoring needs to occur to develop better understanding of these systems and new protocols need to be developed to help agency staff understand these systems and do appropriate projects.

Alluvial fans provide great land for vineyards and orchards due to their good drainage; however, land use on these fans has greatly impacted salmonid populations. Alluvial fans serve as fish migration corridors and in low water or changed conditions may not support adequate periods of connected flow. In order for restoration projects to be successful, the functions of alluvial fans in salmonid migration and the intermittent nature of stream flow should be recognized. Additionally, revegetation of alluvial fans needs to reflect the non-riparian nature of these areas and will require greater monitoring and experimentation.

Management Implications

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Bill Christian, Amargosa River Project Director, Nature Conservancy
Desert Episodic Streams – The Regulatory Framework

Tom Spittler, California Geological Survey
Implications of Urbanization on Alluvial Fans

Andy Collison, ESA-PWA
Large-scale Solar Energy Project Development on Alluvial Fans

Kris Vyverberg, California Department of Fish and Game
Project and Conservation Challenges in Dryland Streams

Desert Episodic Streams - The Regulatory Framework

Bill Christian - *The Nature Conservancy*

[**Presentation**]

The regulatory framework surrounding the desert episodic channels is relatively new, currently complex, and very difficult to navigate. Currently, federal, state and local agencies share the regulatory burden in these systems under creative federalism which has come under pressure due many state and federal laws associated with renewable energy. The federal government and the states have recently forged some partnerships and tried merge and blend their regulatory systems in ways to protect these lands but moreover to expedite the permitting of these gigantic renewable energy facilities. Established in 2002 under Senate Bill 1078 and accelerated in 2006 under Senate Bill 107, the California's Renewables Portfolio Standard (RPS) program requires investor-owned utilities, electric service providers, and community choice aggregators to increase procurement from eligible renewable energy resources by at least 1% of their retail sales annually, until they reach 20% by 2010 and 33% by 2020. The 2005 Federal Energy Bill proposes to increase the amount of renewable energy in the grid by producing 10k mw on public lands through Solar, wind, and geothermal. In 2006, California passed AB 32, a climate change legislation that dictates a 25% reduction of GHG emissions from generation by 2020. Finally, the Recovery Act (ARRA) funding allows for 30% of a facilities cost to be granted in subsidies and tax credits. All of these laws, together, have instigated a relative "gold rush" on dessert lands for large solar plants in particular. If oil and gas prices were even higher we'd see an even greater proliferation of these types of projects but right now it's being driven by regulatory pressure. The gap between gas and oil prices and renewable prices is fairly large, particularly for solar.

Desserts are particularly suitable for these large projects because of their high solar insulation (especially the Mojave Dessert) and because these solar plants require vast, contiguous tracts of land (5000 acres). Almost the entire desert land area is open for this development with one million acres of public lands, mostly BLM owned, being sought via rights of way with the exclusion of only a few areas including wilderness, Desert Wildlife Management Areas (DWMAs or tortoise critical habitat), and Areas of Critical Environmental Concern (ACECs). These rights of way are permanent leases, unlike the royalties provided by fuel companies, and so the public does not see the types of returns one would see from the fuel companies' projects. All sites require that the land be completely devegetated, bladed flat, and fenced. These projects also require transmission linkages. In addition to this new pressure, these lands continue to face other development pressure, including: OHV use, grazing, agriculture, mining, urban and commercial development, and invasives. For this reason these areas should be considered environments of critical concern.

The only regulatory foundations for these types of "dry" waters include: listed species, environmental assessment, and land use planning. Direct federal regulation of episodic streams and their associated washes is limited because section 404 of the Clean Water Act specifically has jurisdiction only over navigatable waters and so does not protect these systems. In California, the Department of Fish and Game Streambed Alteration Agreement permit 1600 has the principle direct regulatory power over these types of environs as "waters of the state" and BLM's land use planning laws have a huge effect on how these streams and desert washes are treated. Finally, the Endangered Species Act can impact how these streams are managed.

There is both Federal and State regulations for all of these types of renewable plants. The regulatory schemes overlap and have the same rules for the most part but they have some differences that can conflict. One example is mitigation rules where the Fish and Wildlife Service and the Department of Fish and Game disagree on how the mitigation for these plants should occur. DFG wants the acquisition of private lands for mitigation of lands that are being disturbed and the BLM and FWS feel that money should be spent on public land by investing in protecting it through improvements like tortoise fencing, closing OHV routes, etc. They have a series of Memorandums of Understanding that set up to sort of resolve these conflicts. California has a much more intensive regulatory scheme than other states and is a pretty unusual case. For example, it has state equivalents of federal laws, unlike Nevada, for instance, which does not have a NEPA equivalent law similar to CEQA.

BLM manages almost all the lands being targeted by solar development. Their regulatory system starts out with the Federal Land Policy Management Act (FLPMA) which has in it a specific provision dictating that BLM to confect a specific California Desert Plan. This plan described planning for the entire California desert from Barstow to the Mexican border and from the Nevada border to the San Gabriel Mountains. This led to series of regional plans (NEMO, WEMO . . .) that really define and limit how federal land is managed with specific small area by small area management plans. Unfortunately, when these plans were developed from the 1980s on, renewable energy was not on anyone's radar and therefore BLM is now forced to go back and redo all these plans in the context of the permitting. This is an important provision as they are not free to invent how they regulate these things, they need to go back to the plans and change the plans to manage them differently. Most importantly, almost all of BLM's management planning, particular those driven by habitat and species management, is driven by a single species, the desert tortoise. This is a federally and state listed species and all of these plans are formed around how this species can be recovered. No one really knows the exact reason its population is declining, however, there are a variety of factors that seem to be involved. Finally, BLM is overwhelmed by solar applications, doing almost nothing else with not enough resources to handle all the applications.

The California Energy Commission (CEC) is the principle agency that permits and regulates large facilities above 50mw on a state bases. They do not have jurisdiction of small plants and Photo Voltaic which are regulated by the counties. The CEC goes through a CEQA like process and needs to pay attention to DFG and other statutory rules but has a specific statutory exemption from CEQA. All lands in the state are covered. The BLM now is adopting the CEC analysis so the CEC is governing how these faculties are permitted. These analyses assess impacts broadly and include direct and indirect as well as cumulative impacts. A mitigation hierarchy applies where by significant impact must ameliorate the problem by first avoiding the impacts and then, if this is not possible, to minimize or restore any damage created, and finally, to compensate (which means to acquire property off the site and/or pay money to help agencies to offset the damage created.) CEQA requires "full mitigation." NEPA is an analysis statute that requires full disclosure and the exploration of alternatives and mitigation but does not require permittees to do anything. Combined with CEQA, however, it works pretty well to mitigate impacts.

The Endangered Species Act (ESA) is another law which impacts the permitting of these projects. Again, the state and federal laws are fairly similar although the lists are somewhat different. The California state list contains a few more species and CEQA forces a broader look outside the list. The laws dictate that the project cannot "take" (broadly defined) any listed species or effect habitat adversely. There are ways to circumvent that problem through incidental take permits, Section 7 under the federal and state process and Section 10 on private land.

This single species approach allows for a way to protect ecological systems, which includes episodic streams, through a planning process. Under federal laws they are called Habitat Conservation Plans and under state laws their referred to as Natural Community Conservation Plan. These plans cover multiple species and habitats and defines areas where development is allowed and where mitigation and avoidance it required. This is much better system than relying on a case by cases bases of the ESA. There is a proposal, put together by states and feds, that is particular to the desert called the Desert Renewable Energy Conservation Plan. It defines siting areas and mitigation requirements and is meant to help expedite permitting of these projects in the desert. This plan will include multiple species and habitats

Water and stream bed laws that impact these projects include the Lake & Streambed Alteration Law administrated by the DFG which has powers over "Waters of the State" includes intermittent streams, desert washes. Mitigation under this law requires a 3:1 offset ratio through a fee or easement and includes BMPs and other minimization. National Section 404 (Dredge and Fill--wetlands) does not affect these projects as it pertains only to navigatable waters.

Arid streams are directly regulated as state waters and projects in these environs requires federal-state review/permitting process. Combine use of NEPA, ESA, CWA can result in broad protection of habitats and ecological systems, but, because these projects are so big, mitigation may not adequately compensate for the significant destruction of desert washes and intermittent streams. The HCP/NCCP should look to ecosystem values to protect these important habitats.

Implications of Urbanization on Alluvial Fans

Tom Spittler - *California Geological Survey*

[**Presentation**]

Prior to the recent economic downturn there was a great demand for the residential development on alluvial fans in southern California. Although this development was on private land, the geologic factors that could influence public safety are similar for public lands where alternative energy projects are proposed. Why are we developing on alluvial fans? Primarily because they provide ideal conditions for easy development, such as gentle slopes, good drainage, easily manipulated surficial materials, beautiful views, relatively inexpensive land prices, and easy access. Developing alluvial fans is driven by these opportunities, but they are in the context of potential hazards and the resources that are at risk from this development.

The hazards that could affect development on alluvial fans include: floods and debris flows, surface fault rupture, seismic shaking and associated ground failure, landslides and rockslides, hazardous minerals, and wildfire. In 1979 a one-percent chance storm (100-year return frequency storm) following a wildfire in the watershed of Magnesia Spring Canyon in Rancho Mirage, Riverside County, triggered a debris flow and flood that buried numerous houses and caused the death of several people. Based on standard flood models, a storm of this magnitude would not be expected to result in a flood of the size experienced. Because of the stochastic nature of alluvial fan flooding and because the source watershed was burned, the flood was not only possible but could have been anticipated. In addition to the individual debris flow event, future floods and debris flows are now a long-term maintenance issue for this project.

Alluvial fans frequently form along mountain fronts, which are typically bounded by earthquake faults in southern California, and landuse development on a fan may be subject to surface rupture . Alluvial fans with active faults will sometime in the future experience earthquakes and strong seismic shaking, and this could trigger liquefaction of susceptible soils on the fan. Rockslides and landslides hazards are also possible, particularly where a fan abuts a steep mountain front and adjacent to deep washes. Hazardous minerals like radon derived from the San Gabriel Mountains bedrock near Sierra Madre and asbestos where alluvial fans formed below serpentinite bedrock and certain other metamorphic rocks are also of concern. All these hazards can be addressed up front by identifying them and then and planning accordingly.

Wildfire potential is another hazard that can be addressed prior to development planning and can take under consideration climate change predictions. Wildfires, even in a desert scrub environment, are particularly important because debris flows and floods following fires are generally the greatest hazard on many alluvial fans. But these post-fire floods are historically the main source of sands needed replenish southern California beaches as well as to provide new riparian habitat on and downstream of the fan; and development on fans has had the effect of "starving" beaches of sediment. This secondary impact is a part of the long-term maintenance and costs of development on alluvial fans.

Alluvial fans also provide numerous resources including native plants and wildlife, economic minerals, groundwater recharge, recreation, and cultural and historical sites. For development we need aggregate, and alluvial fans are a principle source of this material that is local, washed, sorted and inexpensive. Groundwater recharge is an incredible resource for southern California. Alluvial fans provide good infiltration that allows runoff to be stored as groundwater for future use. Federal lands are often protected for various recreational uses, but this is often not considered in private development. However, more and more, the presence of nearby recreational opportunities is being seen as a means of improving or enhancing the value of a development. Finally, many alluvial fans have important archeological sites like the Blythe Intaglios that are being impacted by development and use of alluvial fans. Although historical and archeological sites on private lands are often small or fragmented, they are still protected under CEQA and activities that could impact them are still regulated.

In order to utilize the opportunities provided by alluvial fans while reducing the impacts of hazards and protecting resources it will be important to recognize all opportunities and constraints up-front, before specific development plans are prepared, and to fit the development to the site. This process involves the up-front identification of the hazards and benefits of: the geologic, seismic, and soil conditions; the hydrologic, water quality, and flooding conditions; the biological and cultural resources; as well as other resources and hazards such as wildfires, aesthetic conditions, recreation and other land use opportunities. Currently, developments are often planned based on set zoning and density requirements. Once the specific design has been prepared, the development design is evaluated to meet the requirements of the California Environmental Quality Act (CEQA) and other regulations. The Alluvial Fan Task Force is attempting to come up with a process to front-load CEQA so that developers and other project proponents do not need to fit their development around CEQA after the development is already planned. This approach will be available in a portal online entitled, "The Integrated Approach for Sustainable Development on Alluvial Fans," and is currently available at: http://aftf.csusb.edu/documents/IA_Final_July2010_web.pdf.

In conclusion, many alluvial fans are desirable sites for development, but fan surfaces may be affected by geologic and wildfire hazards and may include resources that need to be protected. By identifying the hazards and benefits associated with alluvial fans prior to initiating a development design, future developments can be safely and responsibly fit to this dynamic environment. This will aid landowners, developers, planners, regulators and the public in protecting lives, property and resources, including saving on the costs of the development themselves.

Large-scale Solar Energy Project Development on Alluvial Fans

Andy Collison - *ESA-PWA*

[Presentation]

Water is not the only fluid that moves sand around, air also moves sound around. Ephemeral channels are sources of sediment that generate habitat further down wind and downstream. Currently there is a huge "gold rush" occurring for renewable energy development in California. In 2007, 12% of California's retail electricity was from renewable sources and California's Renewable Portfolio Standard has the goal of generating 33% of retail electricity from renewable sources by 2020. Excluding large hydro, "renewables" means solar, wind, geothermal, and small hydro. There are currently 11 large solar projects currently proposed, with approximately 5-10 square miles of direct impact per project, plus indirect impacts and 20-30 more projects are in the pipeline. For an idea of the scale of impacts, cumulatively 20 projects will equal the size of Sacramento, California, contributing to a huge impervious area on alluvial fans and other desert areas. Additionally, there is now huge political and financial incentive to get these projects built and it has led to fast moving field at a large scale of development. Many of these projects are at the interface of alluvial fans and wind sand transport corridors.

If you follow ephemeral channels down to their terminus you will find sand transport corridors. Many of these areas line up with sensitive dune areas. These episodic channels and aeolian corridors link headwaters sediment to downwind dunes which are important habitats and impact sensitive and listed animal and plant species. Development in these areas have many impacts including: direct impacts from size of project footprint (~5 sq. miles each), habitat connectivity barriers, bird impacts (dazzle and frazzle), disruption to drainage network, and disruption to dunes by blocking aeolian transport.

Ephemeral channel processes and wind corridor processes interplay. In the upper reaches the ephemeral channels have a high width to depth ratio where water and sediment can easily flow out. In the lower reaches the landscape moves from water controlled landscape to wind control landscape.

Although these windblown areas are also subject to similar timescales of disturbance as the ephemeral channel areas, characterized by long periods of boredom surrounded by brief moments of terror, these windblown systems operate on different climatic time scale (El Nino vs. La Nina). During wet El Nino winters sediment is produced and works down through the fluvial system and will be deposited at the bottom of the alluvial fan. This sediment will stay deposited for several years until the dryer La Nina years, when vegetation is sparser and the sediment is dry and more mobile and is transported downwind to dunes. This interplay of sediment production during El Nino, temporary storage, and then Aeolian transport during an El Nina defines these two systems and their relationship.

Development, particularly solar facilities disrupt both water and wind transport processes though fencing, flood control facilities, wind fences and other infrastructure. All these block wind and water processes disrupting sediment supply, ultimately depleting dunes downwind. The freeways in these areas currently give a foretaste of how disruptions will impact these processes. For instance, Highway 40 includes a serious of interceptor berms which were built to focus drainage through culverts under the highway. Above the road there are shallow wide channels where it is easy for the sediment and water supply to move out on the floodplain. The concentrated drainage below the culverts produces areas of water depletion where the fine sediment, trapped behind the culvert, is depleted creating less active areas and less hydrologically and ecologically productive below the road. This demonstrates what might happen if the business as usual drainage plans were to be implemented around these new facilities. There are now proposals to move away from this by trying to redisperse the drainage. The idea is to capture the drainage at the top, wrap it around the site, and disperse it below.

How effective is this considering the episodic nature of these systems? Most of these systems don't flow until a 3-5 year flow at which time it will pick up a lot of debris and sediment and it is difficult to see these systems working well when there is a large pulse of sediment moving through them. These facilities are also huge blocks to wind transport in these areas which is a very sensitive process, happening within a few inches of the ground, and are easily disrupted. Even a tortoise fence, which is within eighteen inches of the ground, could stop a lot of sand transport creating a "sand shadow" downwind.

Wind fences in Antelope Valley, Western Mojave Desert, were found to reduce dust transport by 80% close to the ground level. Note that due to its greater mass, sand is more effectively trapped by obstructions than dust. When upwind sand supply is disrupted sand dunes rapidly erode and lose habitat value. It takes only months to strip dunes of sand if sediment transport is disrupted.

In terms of a planning process, we need to start putting numbers on this information and model potential impacts of these facilities on these interplaying systems. Sand dunes can be used to determine prevailing wind direction and using weather data secondary wind currents can be identified. Using this information, a model can predict how big an area downwind will be impacted by the facility. An initial proposal for one solar plant modeled 1000 acres of indirect impact in addition to the direct impact of building the facilities with up to 100% reduction of sand transport directly below the facility. After modeling different scenarios, the alternative proposed and assessed for permitting pulls away from the corridor and reduces the impact of the facility.

This type of modeling points the way to redesigning project to decrease their impact. Another example is a proposed substation in which the initial proposal planned for the station in the direct path of the sand transport corridor blocking it off completely. Fairly simple things can be implemented to reduce the impact of this facility. For instance, a snow plow fence to deflect sand around it the station can reduce the area of impact. The snow plow fence coupled with turning the facility on its side further reduces the impact.

Ephemeral channels are important pathways for sediment from headwaters to dune habitat. Water is not the only sediment transporting fluid! Maintaining sediment continuity where possible is important to protecting critical dune habitat and therefore sediment must be thought of as an ecological resource. Analogous to the "Low impact development" principal, sediment dispersal is better than concentration. If disruption to sediment transport is unavoidable, a project needs to either design solutions to reduce the impact or be prepared to mitigate heavily (1,000s of acres). Mitigation is not really an option for some of these projects due to the vast amounts of land needed for the facilities and most of the lands targeted are public and so it is difficult to buy up land to mitigate in the first place. Finally, monitoring needs to be scaled to the frequency of disturbance (i.e. more than the now commonly used 3 years) and must at least be as long as an El Nino/La Nina cycle and should potentially be done for the life of project.

Project and Conservation Challenges in Dryland Streams

Kris Vyverberg - *California Department of Fish and Game*

[Presentation]

One of the most startling paradoxes of the world's drylands is that although they are lands of little rain, the details of their surfaces are mostly the products of the action of rivers. To understand the natural environments of drylands is to understand the process and forms of their rivers.

W.L. Graf (1988)

In mid-2009 Kris Vyverberg, of the California Department of Fish and Game (DFG,) was asked by a regional colleague to provide a second opinion on whether any streams were present on a 6,000+ acre project area located in the Colorado Desert. The project consultant maintained there were no streams, or that if there were a few then they certainly were not subject to Department jurisdiction. Kris located the project area on Google maps, reviewed a few photos from her colleague and fairly quickly concluded that by the department criteria in long use these features would certainly be considered streams subject to DFG jurisdiction.

So what criteria or on what basis had the project applicant concluded otherwise? Partly it was due to the mapping methods used and partly this conclusion was reached by applying the definition of a stream contained in CCR Title 14, section1.72:

"*…is a body of water that flows at least periodically or intermittently through a bed or channel having banks and supports fish or other aquatic life. This includes watercourses having a surface or subsurface flow that supports or has supported riparian vegetation.*"

Specifically, this conclusion was made by interpreting the phrase "periodic and intermittent" to exclude ephemeral streams that only flow in direct response to precipitation. There are several important points about the stream definition used on this project: Title 14, section 1.72 does not pertain to the Department's authority as embodied in the Fish and Game Code, and this is not the stream definition used in practice by the Department. Moreover, references to intermittent flow in other Title 14 sections that do speak to the application of the Fish and Game Code have long been recognized by the courts to include streams with ephemeral flows. Fish and Game Code section 1602 state, "... an entity may not substantially divert or obstruct the natural flow of, or substantially change or use any material from the bed, channel, or bank of, <u>any</u> river, stream, or lake..." unless certain conditions are met. Note the emphasis on <u>ANY</u> stream and absence of defining or limiting criteria such as channel size, or the area associated with a particular flow event, like the regularly used bankfull flow, or the time period between flow events. Fish and Game Code <u>jurisdiction is not</u> predicated on the size of a stream, the morphology of the stream or how well-defined its banks are, the cross-sectional area occupied by particular flow events or the time period between flow events, nor the constancy of water flow.

In practice, the Department of Fish and Game defines a stream as:

> "...a body of water that flows perennially, intermittently, or ephemerally and that is defined by the area in which water currently flows, or has flowed over a given course during the historic hydrologic regime, and where the width of its course can reasonably be identified by physical or biological indicators."

Fish and Game Code links stream protection with the presence of fish, wildlife, <u>and their habitat</u> and meaningful habitat protection must include protection of the physical processes that create and maintain the habitat that plant and animal species depend on for their survival. This means "...all wild animals, birds, plants, fish, amphibians, invertebrates, reptiles, and related ecological communities, <u>including the habitat upon which they depend</u> for continued viability (FGC Division 5, Chapter 1, section 45, and Division 2, Chapter 1, section 711.2(a), respectively).

Two separate methods were used to define and delineate streams in the project area mentioned above: the California Rapid Assessment Method (CRAM) and Rosgen's Stream Classification System. The consultant acknowledged the limitations of both methods as stream delineation tool CRAM because, as stated in Collins *et al.* (2008): *"There may be a limit to the applicability of [this method] in low order (i.e., headwater) streams in very arid environments that tend not to support species-rich plant communities with complex horizontal and vertical structure."* And the Rosgen system because of its dependence on temperate region stream processes and forms. Nevertheless, the consultant went on to conclude based on the application of CRAM that the discontinuous ephemeral channels on site "...are simply erosion features created by runoff...are not representative of riverine features supporting aquatic life or aquatic functions…and result from focused erosion that occurs on an infrequent basis during episodic storm events…" and as such these features do not represent streams relative to CRAM. Similarly, in regards to Rosgen, the consultant concluded that "…the channels observed on site are actually representative of flood prone areas and that the banks observed with these channels are really the floodplain terraces, and that the bankfull stage and OHWM, if present as a result of water flow in most years, would be well contained within these observed terraces." This conclusion can be seen as an attempt to fit the streams observed on site into a temperate region morphology all the while concluding that no streams actually existed.

In the Mojave, a project used a similar stream definition but with the additional requirement that jurisdictional streams have well-defined channel forms. In the aerial photography of the site many stream features can be seen. There are fairly well-defined single-thread channels. The substrate materials over or through which some of the streams flow appear to be more permeable alluvial materials; in other areas the surface appears to be older, possibly less permeable fan surfaces. A larger single-thread channel emerges from a steeper gradient area and splits into a distributary network of smaller channels on the valley floor. Finally, some of the stream channels appear continuous across the field of view; others to alternate between defined and undefined channel segments; and still others peter out and disappear altogether.

With this information a conceptual model of the stream processes and forms likely to be found on site can be develop in a nascent stage. A conceptual model of stream processes and forms should include:

- Highly variable runoff between permeable versus relatively impermeable surfaces.
- Downstream decreases in flow volume due to water losses into alluvial substrates that results in
- Discontinuous sediment transport that in turn results in
- A fabric of single-thread channel forms, distributary channel forms, well-defined erosional channel segments that alternate with depositional reaches lacking defined channel form, and channels that simply end as their flows infiltrate into the valley alluvium.

On the ground, streams appear to be well-defined erosional reaches or transport reach channels that alternate with depositional reaches and a network of distributary channels with poor channel definition. Streams were actually mapped for the purpose of determining the extent of jurisdictional stream acreage that will be destroyed and that will have to be mitigated for as part of project development.

Although there is clearly mappable surface evidence of hydrologic connectivity between these stream reaches, the stream habitat mitigation acreage was based solely on those snippets of stream with well-defined channel form within the project boundaries. The project currently proposes that streams entering the site will be concentrated and redirected away from the project area. This will mean that streams within the project boundary will cease to exist and stream reaches downstream of the project area will no longer receive the naturally diffused flow and water distribution as before.

Fish and Game Code section 1602 protecting streams is not an accounting system for stream length about to be lost, but a process by which associated biological resources will be protected and conserved. Although the project map is probably a good map of where well-defined channel reaches are located and likely a good starting point for measuring the area of the landscape occupied by such channels, as with the Colorado Desert example, what is missing is a complete accounting of the entire episodic stream system as defined by hydrologic connectivity and any consideration of how project-related alterations to stream processes within the project area might detrimentally impact the stream ecosystem outside of project boundaries.

With our understanding of physical processes these types of systems perform, sustainable project development that protects capital investment over a meaningful project lifespan depends on siting decisions and project designs that address the physical processes active on the project landscape. Similarly, environmentally compliant or sensitive project design depends on siting decisions and project designs that acknowledge and address the physical processes active on the project landscape. Both of these goals depend on being able to recognize and account for episodic stream processes and forms and their relation to ecosystem function. Plus, these goals ultimately depend on the consistent use of a single science-based definition of a stream and a stream ecosystem mapping and delineation method suitable for use in our dryland landscapes.

Projects that do not make appropriate siting decisions invariably require subsequent measures to protect project performance and initial capital investments. These after-the-fact protective measures often necessarily extend beyond the original project footprint. The natural environment is rarely immune to the impacts of such expansions.

Challenges of Mapping and Assessment

November 9, 2010

Jeremy Lancaster, California Geological Survey

Geologic and Geomorphic Mapping as a Precursor to Hydrologic Modeling of Episodic Channels on Alluvial Fans

Katherine Curtis, U.S. Army ERDC/CRREL

Challenges of Identification and Mapping the OHWM

Todd Keller-Wolf, California Department of Fish and Game

Mapping Vegetation Defined and Controlled by Fluvial Processes in the Drylands of California

Eric Stein, Southern California Coastal Water Research Project

Challenges in Assessing Condition of Episodic Streams

Geologic and Geomorphic Mapping as a Precursor to Hydrologic Modeling of Episodic Channels on Alluvial Fans

Jeremy Lancaster - *California Geological Survey*

[Presentation]

The Nature of Alluvial Fan Flooding

Riverine flows behave in a reasonably predictable regular manner. Where stream gages have measured river flows for tens of years or more, the relationship between the magnitude of a flood and its probability of occurrence can be statistically estimated (Dunne and Leopold, 1978; IACWD, 1982; Waananen and Crippen 1977). The volume of water carried by a flood of a given probability, such as the one-percent flood (100-year flood) can then be compared with the local topography to determine the flood hazard on floodplains along rivers and streams.

Alluvial fan floods behave differently from riverine floods, and few streams on alluvial fans are gaged. A stream on an alluvial fan may be dry for many years until a rainstorm in the watershed above the fan triggers flow down the mountain channels and onto the fan, often referred to as a "flash flood." Calculating a flood with a specific recurrence interval, such as the 100-year flood, may not adequately identify the magnitude of the flood of concern, nor the specific flow path of that flood. This is illustrated by the 1979 flood that occurred in Magnesia Spring Canyon in Rancho Mirage, Riverside County; this flood buried numerous houses and caused one death. On alluvial fans, the flow paths below the fan apex is uncertain and periodic deposition of sediment in active channels can affect the ability of a channel to carry water and sediment. Additionally, debris flows are common on some alluvial fans and these behave differently from clear water riverine floods. A debris flow is defined as having 60-percent or more of entrained sediment and debris, so it would have a volume of over two and one-half times greater than that of a clear water flood. Sediment deposited in a stream channel by a debris flow may rapidly aggrade or overtax active channels, and result in channel avulsion (the abandonment of the existing channel for a new one). Debris flows are typically controlled by hillslope characteristics, such as slope steepness, geomorphic maturity, regolith (soil thickness), and vegetative characteristics. Debris flows along channels do not occur at a frequency that readily permits an accurate probability assessment of magnitude (consisting of water and sediment) versus frequency. The relative dearth of recorded debris flow events for individual watersheds, the stochastic nature of debris flows, and the uncertainty in volume of debris mobilized, all contribute to the difficulties in establishing accurate debris flow magnitudes and recurrence interval similar to flood probabilities used for more typical riverine engineering flood analyses.

Relationship between Geomorphology and Alluvial Fan Flooding

The expression of landforms on the surface of an alluvial fan system is the result of long-term depositional patterns where a mountain stream flows out onto a valley floor. This is because over time as changes in slope of confined mountain streams and changes in sedimentation rates occur, the fluvial system responds by down-cutting though older deposits. This results in abandonment of geomorphic surfaces or deposition of sediment and debris that covers older geomorphic surfaces. Mapping the Quaternary (about the past 2.5 million years) geology of alluvial fans provides information on the presence, distribution, areal extent, and relative age of alluvial deposits that are useful in the preliminary identification of potential alluvial fan flood hazards. The youngest geomorphic surfaces tend to retain their primary depositional features, such as bar and channel morphology, which are progressively modified by surface processes with time, so that original depositional features are no longer present. Key relationships between geomorphology and the degree of fluvial activity on a fan are drainage network patterns. Such that:

- Alluvial fan surfaces that have the highest potential for alluvial fan flooding are hydrologically connected to the upland watershed and tend to contain distributary drainage networks,
- Older alluvial fan surfaces are commonly dissected with tributary drainage networks that are not connected to the upland drainage basin by a feeder channel have the lowest potential for alluvial fan flooding.
- Height of geomorphic surface above modern drainage pathways also serves as an indicator of the connection, or lack thereof with the upland watershed.

The Association of Alluvial Fan Geology and Geomorphology with Alluvial Fan Flooding Assessments

The use of surficial geologic maps and geomorphic site assessment to identify the relative hazard (or instability) of alluvial fan systems from a given location is a useful and cost effective preliminary assessment tool. Geomorphology is a reflective of long-term erosional and depositional patterns, and provides clues to the distribution, areal extent and relative age of deposits. Surficial geologic maps can be used to focus attention on hazard assessments on those areas where alluvial fan flooding has most recently occurred (Pearthree and Pearthree, 1988, cited in Field and Pearthree, 1997). Surficial geologic maps may be used to help:

- Identify potentially hazardous areas
- Distinguish areas of primarily flood-dominated and debris flow-dominated processes
- Identify areas where disturbances to natural flow patterns have, or may occur
- Provide a basis for identifying areas that may require focused engineering studies
- Provide a check on flood models

Mapping Assessment Approach

Engineering geologic maps developed from surficial geologic maps, historic photographs, flood maps, historical accounts, and field investigations may be used to identify the type of fan, the relative age of fan surfaces, presence and nature of potential channel diversions, and anthropogenic disturbances that may modify flood flow patterns. This information can then be used to identify areas with relatively higher, relatively moderate, and relatively lower potential for alluvial fan flooding.

This method separates alluvial fan surfaces into categories based on the relative likelihood of alluvial fan flooding based on the Quaternary geology and geomorphology. Surficial geologic maps may be used to address the types of alluvial fan deposits and the relative ages of sediments on alluvial fans, and to provide a preliminary assessment of the relative potential for alluvial fan flooding on various portions of a fan. Additional information, such as the potential for avulsion, may also be considered in the assessment of alluvial fans. Surficial geologic mapping coupled with site assessments may be used to develop a preliminary ranking of an area of study as:

Relatively High – Historic channels and washes (also referred to as arroyos), and whole fan areas subject to historic and future migration of flow paths. This may include debris flow deposition areas of Holocene age (about the past 12,000 years).

Relatively Moderate – Alluvial fan terraces (abandoned surfaces) that are moderately incised and raised above surrounding historic channels and washes. These areas are generally considered to have a moderate hazard. Fan terrace surfaces that are narrow interfluves surrounded by or interwoven with historic channels are typically included with the High areas. See discussion of mapping scales, below.

Relatively Low – Relict fans, or adjacent surfaces of deeply entrenched fan heads containing well-developed soils that are elevated above active washes.

Debris Flow Hazard Area – Fan areas with geomorphic and geologic evidence of Holocene (last 10,000-12,000 years) debris flow deposition. (**Note:** Because of the potential large volumes of debris flows, and randomness of their flow paths, this method only provides a very general indication of the susceptibility of the whole fan (topographic apex to toe) area to debris flows, and cannot be used solely as a method to predict specific areas of future debris flow deposition.) These areas are typically included in the high hazard category.

Uncertain due to Disturbance – Areas where disturbances to natural flow patterns have occurred (e.g. roadway construction or other development) and the relative hazard cannot be reliably mapped at or below the disturbed areas.

Non-Fan Unit – Bedrock and other areas bordering alluvial fans that are not composed of alluvial fan, or alluvial wash deposits, and do not show evidence of alluvial fan flood flows.

An active wash on an alluvial fan, which has little soil development, few plants, and lies along a topographic trough, is considered to have a relatively high potential for alluvial fan flooding. Topographically above these, alluvial fan surfaces adjacent to moderately incised and raised channels and washes where some soil and vegetation development has occurred are identified as having a relatively moderate potential for flooding. These surfaces are subject to future flooding, but they are generally less likely to be inundated than the relatively high potential surfaces. Relic surface with deep, well developed soil that are dissected by and well above well-defined channels have not been flooded for tens of thousands of years or more and are considered to have a relatively low potential for alluvial fan flooding. To further complicate the assessment of flood hazards on alluvial fans, some alluvial fan surfaces have been disturbed by land use activities. Where this has occurred, the natural drainage network on the alluvial fan may have been disrupted, and the distribution and depth of future flows on, adjacent to, and down fan from these areas may be affected.

This engineering geologic approach gives an indication of where alluvial fan flooding and debris flow may occur and may be useful in the preliminary assessment of alluvial fan flood hazards where disturbances to natural flow patterns on the fan are minimal. This engineering geologic approach may be used in the qualitative delineation of hazardous areas as part of a planning process, but is not a substitute for quantitative modeling of the potential range of flow depths and velocities that would be consistent with established engineering methods (NRC, 1996). For additional information on this qualitative approach see the Chapter 3 Appendix to the Alluvial Fan Task Force document (AFTF, 2010) titled, "The Integrated Approach for Sustainable Development on Alluvial Fans" (located at: http://aftf.csusb.edu/).

Modeling Approach

Following repetitive losses in populated areas located on alluvial fans during the 1970s the Federal Emergency Management Agency (FEMA) concluded that standard flood hazard mapping for riverine systems did not adequately perform on alluvial fans because of the unpredictability of alluvial fan flooding, the high velocities of flow, and the lack of advanced warning time. To address the need for an economical approach to mapping flood risk, FEMA adopted the FAN model (Dawdy 1979) which assumed that flooding on an alluvial fan is completely unpredictable and random. This modeled delineation has not been completely successful in all areas, particularly where alluvial fans include surfaces of various ages and where stable incised channels have formed; additionally the model does not recognize debris flow processes (NRC, 1996). At the request of FEMA, the National Research Council (NRC, 1996) sought to resolve controversial alluvial fan flooding issues by studying the problem, and identifying an approach for assessing alluvial fan flood hazards. This NRC developed a three stage strategy for assessing and delineating alluvial fan flooding hazards:

I. Recognizing and characterizing alluvial fan landforms;
II. Defining the nature of the alluvial fan environment and identifying active and inactive areas of the fan; and
III. Defining and characterizing the 1-percent-annual chance (100-year) flood within the defined [active] areas.

The NRC recognized the role of geology in identifying the presence of an alluvial fan and defining the active and inactive areas, while also understanding the importance of designing for debris flows.

Therefore, when performing an alluvial fan flood hazard assessment, a quantitative modeling approach should incorporate topographic and geomorphic mapping to assist in identifying the most important areas to be considered for modeling. The advantages to performing relative hazard mapping using surficial geologic maps and site assessments are that it is cost effective and provides information on the stability of alluvial fan surfaces, and can be used in pre-project planning for a proposed project. The mapping-based approach provides an indication of the relatively more and less hazardous areas on a fan and can ultimately provide input to the quantitative analyses and hydrologic/hydraulic modeling necessary to provide design information for a project.

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Challenges of Identification and Mapping the OHWM

Katherine Curtis - *U.S. Army ERDC/CRREL*

[**Presentation**]

The Ordinary High Water Mark (OHWM) is regulated under Waters of the US in Section 404 of the Clean Water Act and is defined as:

"Line on the shore established by the fluctuations of water and indicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas." (33 CFR Part 328.3)

This definition is admittedly vague and subject to interpretation. However, the Corps has developed methodology to create a repeatable and reliable methodology for identifying the OHWM. The bank full term is misleading for episodic channels because in eastern perennial streams it more closely resembles the OHWM while in western channels, the active channel is the OHWM and typically has a higher recurrence interval than 1.5-2 yrs. The Corps has identified geomorphic signatures generally including a main active channel with a washed out look where there is scouring and water has obviously been, and changes in vegetation including identification of the water line below vegetation growth as well as transitions from younger to well established growth. Flow indicators have also been identified including: mud cracks, cobble bars, changes in particle size, ripples, benches, drift, break in slope, and silt deposits.

However, when flow indicators are compared with inundation extents for modeled flood events, it appears indicators are randomly distributed. Original hypotheses were that flow indicators are clustered around the outer extent of the last event, with a few indicators placed within the channel as the floodwaters recede. Statistical analysis of the distribution of indicators in relation to flood inundation levels demonstrate the distribution cannot be distinguished from random. The most repeatable features in the channel to identify the OHWM are the geomorphic signatures of the active zone, including the sparsely vegetated region and texture changes.

This distribution of indicators was determined from data collected by Army Corps staff at Mission Creek, CA between September 2003 and September 2005. The sites were chosen based on the availability of long-term gauging records and minimal anthropogenic influence. High-Resolution Topography was mapped using NASA – ATM-III LIDAR. Using USGS hydrographs the 5, 25, 100 year floods were determined and modeled in HEC-RAS (hydraulic engineering centers river analysis system).

The investigators were interested in looking at identifying possible relationships between mapped characteristics and spatial position within the cross-section. The low flow channels were defined by bed/bank features presumed to be products of frequent discharges. The active channel was determined where frequent overbank flow developed a geomorphic signature such as a lack of vegetation and a break in slope. The terrace was identified as the paleo surfaces that infrequently receive floodwaters. Polygons were then mapped for fluvial surface, sediment characteristics and vegetation (strata, dominate species, and percent cover). The inundation extent of 10yr, 25yr, and 50 year events were modeled and compared with the indicators' GPS data to determine how well the indicators were associated with the events. Results demonstrated that you could not distinguish whether or not the indicators were randomly distributed and therefore indicators were not very useful in delineating the OHWM.

Gages were then used to investigate ways to determine the OHWM. A diverse group of sites throughout the southwest with varying watershed area and duration of flow were used. The position of the gage-predicted OHWM determined based on a recent flow event was compared to a field geomorphic signature. Challenges to using gages included the need to know when most recent low to moderate flood occurred and the flow history of channel. It was found that the gage data had a higher predicted recent flow then the field OHWM signature. The recurrence interval of the field OHWM geomorphic signature was found to be specific to an individual reach and varied from <1-15.5 yrs. Despite this variation, certain trends were highlighted. Channels with more sediment availability typically have higher recurrence intervals than more stable channels that are more incised or have larger sediment size. Gages are limited in their usefulness in identifying the OHWM because of the high variability of recurrence intervals but they do give insight into recent events and flow dynamics of a channel.

The most repeatable and reliable methodology for OHWM determination is the mapping of the sites physical features. The procedure for mapping these features includes looking for scoured areas that show a break in slope and vegetation changes. The vegetation trends, including bare ground/herbs associated with active floodplain and trees associated with the terrace, were mapped. These signatures were then mapped on aerial photographs.

Watershed scale mapping can also be done by mapping the vegetation community at two scales, rating the vegetation units for wetland potential, and overlaying the vegetation units and fluvial surfaces. The product of overlaying fluvial and vegetation units develops an OHWM Regulatory Rated Map.

The biggest challenge with the identification and mapping the OHWM is defining the active-terrace boundary. The key is to use the geomorphic signature including texture changes, vegetation characteristics, and break in slope. Flow indicators may be useful in helping to identify the floodplain units, but the distribution of indicators cannot be distinguished from random. Gage data provides insight into flow dynamics but recurrence intervals are highly variable. A field signature should be identified and mapped for reliable and repeatable delineations.

Mapping Vegetation Defined and Controlled by Fluvial Processes in the Drylands of California

Todd Keeler-Wolf - *California Department of Fish and Game*

[**Presentation**]

Wash/episodic channel vegetation can be defined. There are predictable species that can be considered good indicators of vegetation types and correlated with process intensity, frequency, and substrate variation. These species can be arranged ecologically and geographically. Characteristics of these plant species are based on dominance, and/or diagnostic value and can be correlated with the environment at a local and/or regional level. Definitions are based on quantitative relationships determined through the analysis of multiple stand samples and by using descriptions and keys

In order to quantify the relationships between the vegetation types and the fluvial processes, parameters were visually delineated and 400 m repeated sample were performed to inform cluster analyses. Sets are then pulled out to identify episodic channel species. Vegetation types were ordinated to a gradient and significant values of distribution over the wash were correlated with the ends of wash and imported sediment/elevation factors. It was found that species correlated with specific characteristics of the washes and that one can key out vegetation based on wash vegetation type.

Wash Vegetation Types

Episodic wash woody plants are deep rooted, long-lived species or shallow-rooted, short-lived species. Long Lived species produce long dormant seeds that “wait” for specific germination conditions. Once established these plants require deep rooted connections to a reliable water source. Short lived species produce seeds with usually short viability. These seeds tend to be easily dispersed by the wind and are opportunistic especially in areas that have experienced a disturbance. Many are not strictly restricted to washes, but occur as disturbance followers. It’s often the combination of short and long lived species that characterize a specific plant association. Diagnostics tend to be a genus level, although different levels can be diagnosed within the wash landscape.

Examples of diagnostic deep-rooted species in episodic desert systems include

- *Acacia greggi* (catclaw)
- *Olneya tesota*(desert ironwood)
- *Parkinsonia florida* (blue paloverde)
- *Psorothamnus spinosus* (smoketree)
- *Prunus fasciculatum* (desert almond)
- *Chilopsis linearis* (desert willow)
- *Baccharis sergilloides* (desert broom)
- *Hyptis emoryi* (desert lavender)

Examples of shallow rooted species in episodic desert systems include:

- *Ambrosia salsola* (cheesebush)
- *Ambrosia eriocentra* (wooly-fruited burrweed)
- *Salizaria mexicana* (paper-bag bush)
- *Salvia dorii* (desert purple sage)
- *Ericameria paniculata* (black-band rabbitbush)
- *Encelia virginensis* (Virgin River Encelia)
- *Viguieria reticulata* (net-leaved goldeneye)

The National Vegetation Classification is the state and national standard and is the most flexible and defensible approach for episodic stream course vegetation. It is quantitatively based with a hierarchical taxonomy similar to other hierarchical systems such as species taxonomy or soil taxonomy. Below is an example hierarchy:

Class 3. Xeromorphic Scrub and Herb Vegetation (Semi-Desert)
Subclass 3.A. Warm Desert and Semi-Desert Scrub and Grassland
    Formation 3.A.1. Warm Semi-Desert Scrub and Grassland
        Division 3.A.1.a Sonoran and Chihuahuan Semi-Desert Scrub and Grassland
            Macrogroup MG092. Madrean Warm Semi-Desert Wash Woodland/Scrub
            Group - Sonoran-Coloradan Semi-Desert wash

woodland/scrub

Alliance – Blue paloverde-Desert Ironwood

(*Parkinsonia florida–Olneya tesota*)

Association – Blue paloverde/Desert lavender

(*Parkinsonia florida* /*Hyptis emoryi)*

Additionally, the Manual of California Vegetation, Second Edition has most definitions and citations needed for proper identification of episodic stream and riparian vegetation. Field data collection protocols can be found at:
http://www.dfg.ca.gov/biogeodata/vegcamp/veg_publications_protocols.asp

Currently accepted Vegetation types can also be found at:
http://www.dfg.ca.gov/biogeodata/vegcamp/natural_comm_list.asp

Vegetation can be characterized by larger deep rooted species or smaller shallow rooted species, depending on frequency and intensity of fluvial processes. The former are longer lived, the latter shorter lived and typically related to greater frequency disturbance. One should look for the relative difference in species composition between uplands and lowland vegetation. One should also define the wash vegetation based on fluvial processes and relationships between stand edges and the environment. When delineating wash vegetation think systematically and follow a repeatable process.

Mapping Wash Vegetation

When approaching vegetation mapping in these landscapes, the following general considerations should be taken into account:

- Why are you doing this?
- What is the extent of the project?
- What is the scale of your source imagery?
- What is your time frame?
- Are there good quantitative descriptions of the vegetation; at what level of classification?

In order to appropriately map this type of vegetation the appropriate level of classification hierarchy should be used where ever possible. It is important to develop rules for aggregation into mapping units when vegetation is either not discernable or accurately differentiated from other types. Developing the minimum map unit size, width, and mapping unit attributes is also essential.

Mapping should be based on classification and the clear relationship between mapping units and vegetation characteristics. There are several specific mapping issues associated with episodic stream vegetation. These systems have fine scale distributary channels and so it is difficult to define appropriate breaks in delineation due to fractal issues of resolution of stands and correlating environmental variables. There is a fine interplay between imagery, mapability, and resolution. It is important to think about the scale of imagery and to standardize the map attributes and calibrate the photo interpreters. There are several things to keep in mind while mapping episodic stream vegetation. Environmental influences on vegetation patterns include: flooding frequency and intensity, depth to reliable water supply, and rugosity of surface (dendritic micropatterning). Geomorphic features are based on processes over time and space so it is important to tune and retune the vegetation map, correlating vegetation to elevation changes.

Impact Assessment

Many disturbance impacts can be reliably mapped although some can only be reliably interpreted from the ground and some require more time than others to evaluate.

Below are examples of disturbance modifiers that can be used to assess the impacts to these washes:

- High Disturbance: Over 50% of the polygon is affected with roads, trails, disked activity or scrapes on the landscape.
- Moderate Disturbance: Between 25% and 50% of the polygon is affected with roads, trails, disked activity or scrapes on the landscape
- Minimal Disturbance: At least 5% of the polygon is affected with roads, trails, disked activity or scrapes on the landscape. Polygons adjacent to major disturbances are also placed into this category.

Wash and episodic stream channels vary in plant species composition at regional and local scales. Within a single wash system vegetation follows gradients of flooding intensity and substrate characteristics. Within a local area these gradients are similar from wash to wash. Species composition varies from region to region within washes/episodic channels. This means that it is difficult to have a single list of wash indicator plant species for all of the state. Desert washes differ from cismontane channels. Washes in lower deserts differ from washes in high deserts. So, what is the tie that binds definition and delineation of wash/ephemeral stream channels? Wash/episodic stream channel vegetation is best defined relative to the contrasting vegetation outside of the channels. Wash species will vary depending on the ambient water supply (very dry desert vs. Semi-desert for example) and the size of the wash (maximum, minimum, and mean flooding cycles supply water and disturbance regimes). It is imperative to developed rules of evaluation based on a flexible landscape approach.

Challenges in Assessing Condition of Episodic Streams

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[**Presentation**]

Assessing a giant with the ax of a dwarf: how do we take information about the physical processes and forms and ecological implications of episodic streams to create tools on the ground? Important considerations to take into account when approaching these systems is their high variability over space and time. Due to this variability it is difficult to discern "impacts" from patterns of natural disturbance that have subtle field indicators. For this reason traditional assessment tools and indicators may not be appropriate. In developing tools to use in these systems we need to refine our reference based on the lack of anthropomorphic impacts. Indices used for perennial sites may not transfer well to non-perennial sites. For example, non-perennial "reference" streams have been seen to have lower IBI scores than perennial reference streams. The perennial data comes from the calibration and validation of the SoCal IBI (Ode et al. 2005), and consists of 89 data points at different sites. The non-perennial data comes from SCCWRP, and is not yet published. It consists of 29 samples at 5 sites. T-test (alpha = 0.05, unequal variance) p value < 0.0001 (df = 116).

Additionally, physical indicators and indicators for biological structure may also differ. For instance, the CRAM (assessment not mapping) indicators were designed for traditional streams and may not be appropriate for episodic channels.

Considerations for the assessment of episodic streams should include an analysis of where the site is as well as its spatial and temporal scale and the physical and biological indicators.

Due to variability it is difficult to differentiate condition from natural variability on a temporal scale. It will be important to identify the semi-stable field indicators or macro structures that are less variable, conduct base evaluations on ranges of values for key indicators, and identify indicators of repeating patterns of flow or sediment movement. This will most likely include the use of gage data as a measure of system integrity. Considering how indicators vary over time since the last disturbance will be of the utmost importance and expectations should reflect this.

Assessing physical indicators will be particularly challenging as their dynamism may be subtle or hard to measure. Physical indicators that should be considered include the planform structure vs. inchannel features and the prevalence of indicators across the active floodplain. Despite limitations in mapping, the density of indicators may be useful when looking at conditions. Some clue of how disturbed the area is may be found by assessing the landscape context including: hillslope coupling, sediment yield, land use changes, and existing structures.

Streams may lack distinctive riparian communities that have structure and composition features used by traditional assessment methods. Biological indicators may include the connections between the upland and instream communities, the linear corridor continuity, and the "requisite" faunal habitat. In assessing the habitat it will be important to consider the communities position in the floodplain and other species habitat indicators. Floodplain plant composition is also important and an assessment should include: the plant densities and distribution/position across the floodplain, the structural complexity of floodplain plant communities, and the diversity of non-invasive plants. Additionally, the stand age distribution including the seral stage relative to last disturbance and the position of mature vegetation relative to active channel should be assessed.
Additional considerations when assessing these systems should include:

- What is reference?
- Contemporary vs. relict features
- Assess stressors vs. condition
    - Natural
    - Anthropogenic
    - Relationship to integrated regional monitoring

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