National Flood Insurance Program
Community Rating System

Inland Hazards

A Special Flood-related Hazards Supplement to the *CRS Coordinator's Manual*

2013

FEMA

On the cover: Kankakee River ice jam damage, 1982
(photo from French & Associates, Ltd.)

A community interested in more information on obtaining flood insurance premium credits through the Community Rating System (CRS) should have the 2013 *CRS Coordinator's Manual*. This and other publications on the CRS are available at no cost from

Flood Publications
NFIP/CRS
P.O. Box 501016
Indianapolis, IN 46250-1016
(317) 848-2898
Fax: (201) 748-1936
NFIPCRS@iso.com

They can also be viewed and downloaded from www.CRSresources.org

CONTENTS

[This page intentionally blank]

INTRODUCTION

The Community Rating System (CRS) rewards communities that are doing more than meeting the minimum requirements of the National Flood Insurance Program (NFIP) to help their citizens prevent or reduce flood losses. The CRS also provides an incentive for communities to initiate new flood risk reduction activities.

The CRS includes 19 creditable activities, organized under four categories or series:

300—Public Information Activities

400—Mapping and Regulations

500—Flood Damage Reduction Activities

600—Warning and Response

Credit points are based on the extent to which an activity advances the three goals of the CRS. Communities are invited to propose alternative approaches to these activities in their applications.

The Federal Emergency Management Agency (FEMA) and many communities in the United States have long recognized that the mapping and minimum regulatory standards of the NFIP do not adequately address all of the flood problems in the country. In particular, a number of "special" flood hazards deserve attention. They include

- Ice jam flooding,
- Flooding adjacent to closed basin lakes,
- Mudflow hazards,
- Flooding affected by land subsidence,
- Uncertain flow path flood hazards,
- Coastal erosion, and
- Tsunamis.

This publication discusses the credits provided by the CRS for mapping and management of the first five, inland, hazards. Other hazards are addressed in two separate publications:

Coastal Erosion Hazards: A Special Flood-related Hazards Supplement to the CRS Coordinator's Manual, and

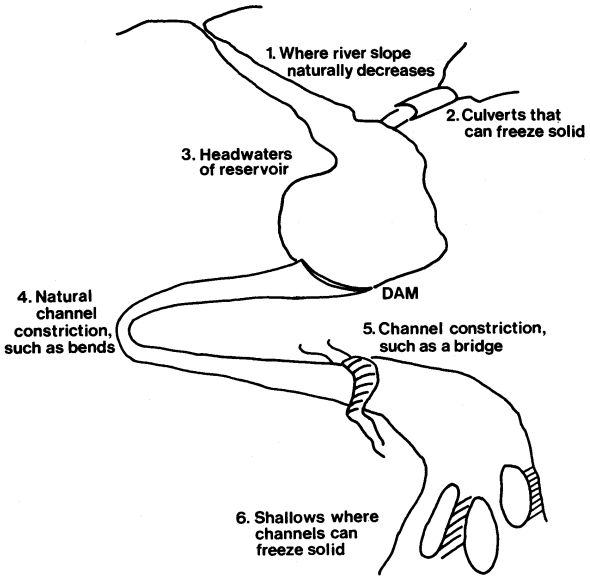
Tsunami Hazards: A Special Flood-related Hazards Supplement to the CRS Coordinator's Manual.

Both may be downloaded from www.CRSresources.org.

BACKGROUND ON SPECIAL FLOOD-RELATED INLAND HAZARDS

Ice Jam Flooding

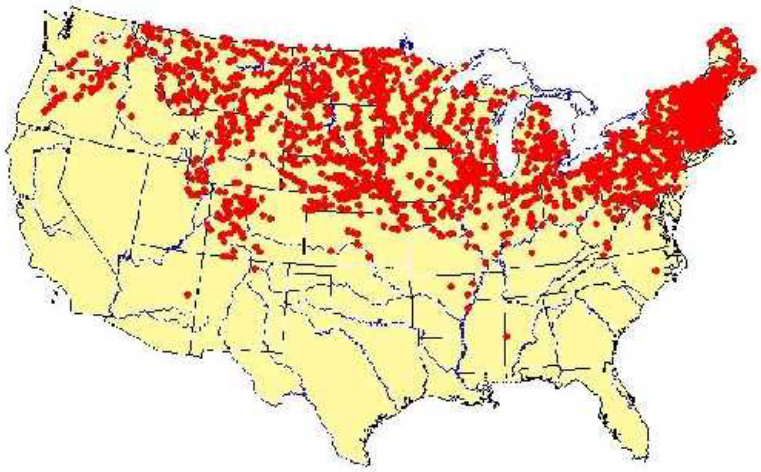
An ice jam may be defined as an accumulation of ice in a river, stream, or other flooding source that reduces the cross-sectional area available to carry the flow and increases the water-surface elevation. Ice usually accumulates at a natural or human-made obstruction or a relatively sudden change in channel slope, alignment, or cross-section shape or depth. Ice jams are common in locations where the channel slope changes from relatively steep to mild, and where a tributary stream enters a large river. Ice jams often cause considerable increases in upstream water surface elevation, and the flooding often occurs quite rapidly after the jam forms (FEMA, 2002).



Typical ice jam locations (from Association of State Floodplain Managers).

In many northern regions, ice covers the rivers and lakes annually. The yearly freezeup and breakup usually take place without major flooding. However, some communities face serious ice jam threats every year, while others experience ice-jam-induced flooding at random intervals. The former usually have developed emergency plans to deal with ice jam problems, but the latter are often ill-prepared to cope with a jam.

In a 1992 survey, the U.S. Army Corps of Engineers District and Division offices reported ice jam problems in 36 states, primarily in the northern tier of the United State. However, even mountainous regions as far south as New Mexico and Arizona experience river ice. Ice jams affect the major navigable inland waterways of the United States, including the Great Lakes. A study



Distribution of ice jam events in the continental United States as of September 1999 (from U.S. Army Corps of Engineers, 2006).

conducted in Maine, New Hampshire, and Vermont identified over 200 small towns and cities that reported ice jam flooding over a 10-year period. In March 1992 alone, 62 towns in New Hampshire and Vermont reported ice jam flooding problems after two rainfall episodes.

Ice jams in the United States cause approximately $125 million in damage annually, including an estimated $50 million in personal property damage and $25 million in operation and maintenance costs to navigation, flood control, and channel stabilization structures.

Ice jam flood on the Iroquois River, Illinois, March 1979 (photo from Kankakee County Planning Department).

Because ice jam floods are less common and more poorly documented than open-water floods, it is more difficult to characterize these events compared to open-water flooding. In addition, because of the complex processes involved in the formation and progression of ice jams and the highly site-specific nature of these jams, these events are more difficult to predict than open-water flooding. The rates of water level rise can vary from feet per minute to feet per hour during ice jam flooding.

There are generally two types of ice jams:

- Frazil ice freezes the river and forms a dam.
- When warm weather and rain break up frozen rivers or any time there is a rapid cycle of freezing and thawing, broken ice floats downriver until it is blocked by an obstruction such as a bridge or shallow area.

In both cases, an ice dam forms, blocking the channel and causing flooding upstream. Ice jams present three hazards:

- Sudden flooding of areas upstream from the jam, often on clear days with little or no warning;
- Sudden flooding of areas downstream when an ice jam breaks. The impact is similar to a dam failure, and damages or destroys buildings and structures; and
- Movement of ice chunks that can push over trees and crush buildings (see photo).

Ice jams tend to recur at the same locations on streams, and ice jam flood elevations have a recurrence interval just like clear water floods. Because freezeup jams rely heavily on periods of intense cold that produce large quantities of frazil ice, they can be somewhat

easier to predict than breakup jams, which are caused by a site-specific combination of complex physical processes. Evaluation of historical ice, meteorological, and hydrological records is necessary for developing a prediction method for either type of jam.

Hazards Related to Closed Basin Lakes

Two types of lakes pose special flood-related hazards to adjacent development: lakes with no outlets, like the Great Salt Lake and the Salton Sea; and lakes with inadequate, regulated, or elevated outlets, such as many glacial lakes. All of these are referred to as "closed basin lakes." Closed basin lakes are subject to very large fluctuations in elevation that can persist for weeks, months, or years.

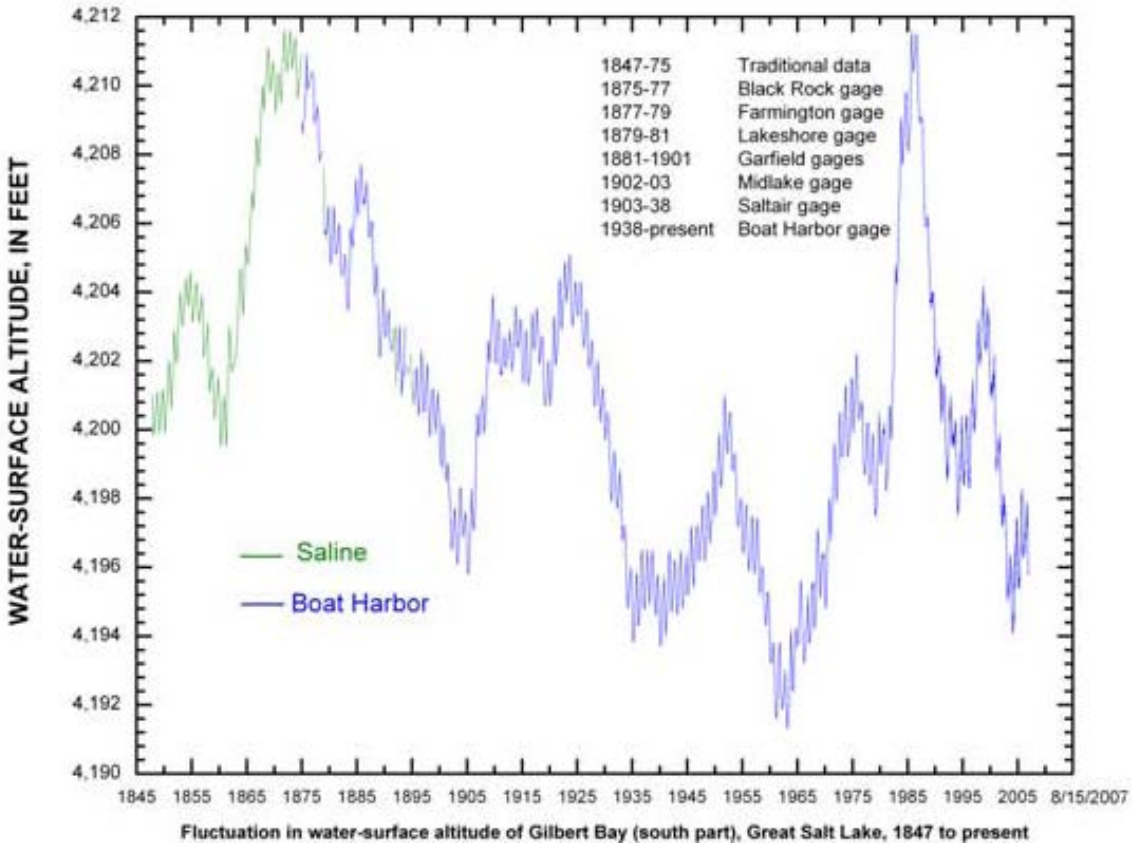
Closed basin lakes occur in almost every part of the United States for a variety of reasons. Lakes in the northern tier of states and Alaska were scoured out by glaciers. Lakes with no outlets (playas) formed in the West as a result of tectonic action. Oxbow lakes along the Mississippi and other large rivers are a consequence of channel migration. Sinkhole lakes formed where there are large limestone deposits at or near the surface and adequate surface water and rainfall to dissolve the limestone (karst topography).

The Great Salt Lake in Utah is perhaps the best known closed basin lake in the United States. There is little permanent development adjacent to the Great Salt Lake, but there is a thriving tourism industry, and roads and railroads near the lake are affected by high lake levels. The graph on the next page shows how the persistence of high (or low) lake levels mean everything to management of development adjacent to closed basin lakes. Imagine that a flood protection level for the Great Salt Lake were set at 4,212 feet msl. No buildings would have flooded during the 185 years of lake level records.

Hazards Related to Mudflows

Mudflows (or debris flows) are rivers of rock, earth, and other debris saturated with water. They occur when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt, changing the earth into a flowing river of mud or "slurry." A mudflow can flow rapidly down slopes or through channels, and strike with little or no warning at avalanche speeds. A mudflow can travel several miles from its source, growing in size as it picks up trees, cars, and other materials along the way.

Although floods and mudflows are covered under the NFIP, landslides are not covered. Typically, a combination of flooding, mudflow, and landslide conditions can occur at the same time in the same general area. Under a flood insurance policy a property is covered for the portion of the damage to the insured building or contents caused by the flooding and mudflow, but not the portion of the damage caused by the landslide.



Level of the Great Salt Lake, Utah, 1847–2007. The Great Salt Lake is located on a shallow playa, so small changes in the water surface elevation result in large changes in the surface area of the lake. This is particularly evident when the lake spills into the west desert at an elevation of about 4215 feet, greatly increasing its area. ... At the historic average (1847-1986) surface elevation of 4,200 feet ..., the lake covers an area of about 1,700 square miles. At the historic low elevation of 4,191.35 in 1963, the lake covered only 950 square miles. The drop of about 8.5 feet in elevation resulted in a loss of about 44 percent in surface area. During 1986 and again in 1987, the lake reached an elevation of 4,211.6 feet and had a surface area of about 3,300 square miles (USGS, 2007).

Mudflows are common types of fast-moving landslides. These flows generally occur during periods of intense rainfall or rapid snow melt. They usually start on steep hillsides as shallow landslides that liquefy and accelerate to speeds that are typically about 10 miles per hour, but can exceed 35 miles per hour. The consistency of debris flows ranges from watery mud to thick, rocky mud that can carry large items such as boulders, trees, and cars.

Mudflows from different sources can combine in channels, and their destructive power may be greatly increased. They continue flowing down hills and through channels, growing in volume with the addition of water, sand, mud, boulders, trees, and other materials. When the flows reach flatter ground, the debris spreads over a broad area, sometimes accumulating in thick deposits that can wreak havoc on developed areas.

Hazards Related to Land Subsidence

The U.S. Geological Survey (USGS) and others have been studying the phenomenon of land subsidence, its causes, and its impacts for at least 100 years. USGS Circular 1182 provides background information on land subsidence and case studies, quoted below.

> Land subsidence is a gradual settling or sudden sinking of the Earth's surface owing to subsurface movement of earth materials. Subsidence is a global problem and, in the United States, more than 17,000 square miles in 45 States, an area roughly the size of New Hampshire and Vermont combined, have been directly affected by subsidence. . . . More than 80 percent of the identified subsidence in the Nation is a consequence of our exploitation of underground water, and the increasing development of land and water resources threatens to exacerbate existing land subsidence problems and initiate new ones. In many areas of the arid Southwest, and in more humid areas underlain by soluble rocks such as limestone, gypsum, or salt, land subsidence is an often-overlooked environmental consequence of our land- and water-use practices (Galloway et al., 1999, p. 1).
>
> In 1991, the National Research Council estimated that annual costs in the United States from flooding and structural damage caused by land subsidence exceeded $125 million. The assessment of other costs related to land subsidence, especially those due to groundwater withdrawal, is complicated by difficulties in identifying and mapping the affected areas, establishing cause-and-effect relations, assigning economic value to environmental resources, and by inherent conflicts in the legal system regarding the recovery of damages caused by resource removal under established land and water rights. Due to these "hidden" costs, the total cost of subsidence is probably significantly larger than our current best estimate (Galloway et al., 1999, p. 1).
>
> Several other types of subsidence involve processes more or less similar to the three mechanisms just cited, but are not covered in detail in this Circular. These include the consolidation of sedimentary deposits on geologic time scales; subsidence associated with tectonism; the compaction of sediments due to the removal of oil and gas reserves; subsidence of thawing permafrost; and the collapse of underground mines. Underground mining for coal accounts for most of the mining-related subsidence in the United States and has been thoroughly addressed through Federal and State programs prompted by the 1977 Surface Mining Control and Reclamation Act. No such nationally integrated approach has been implemented to deal with the remaining 80 percent of land subsidence associated with ground-water processes (Galloway et al., 1999, p. 3).

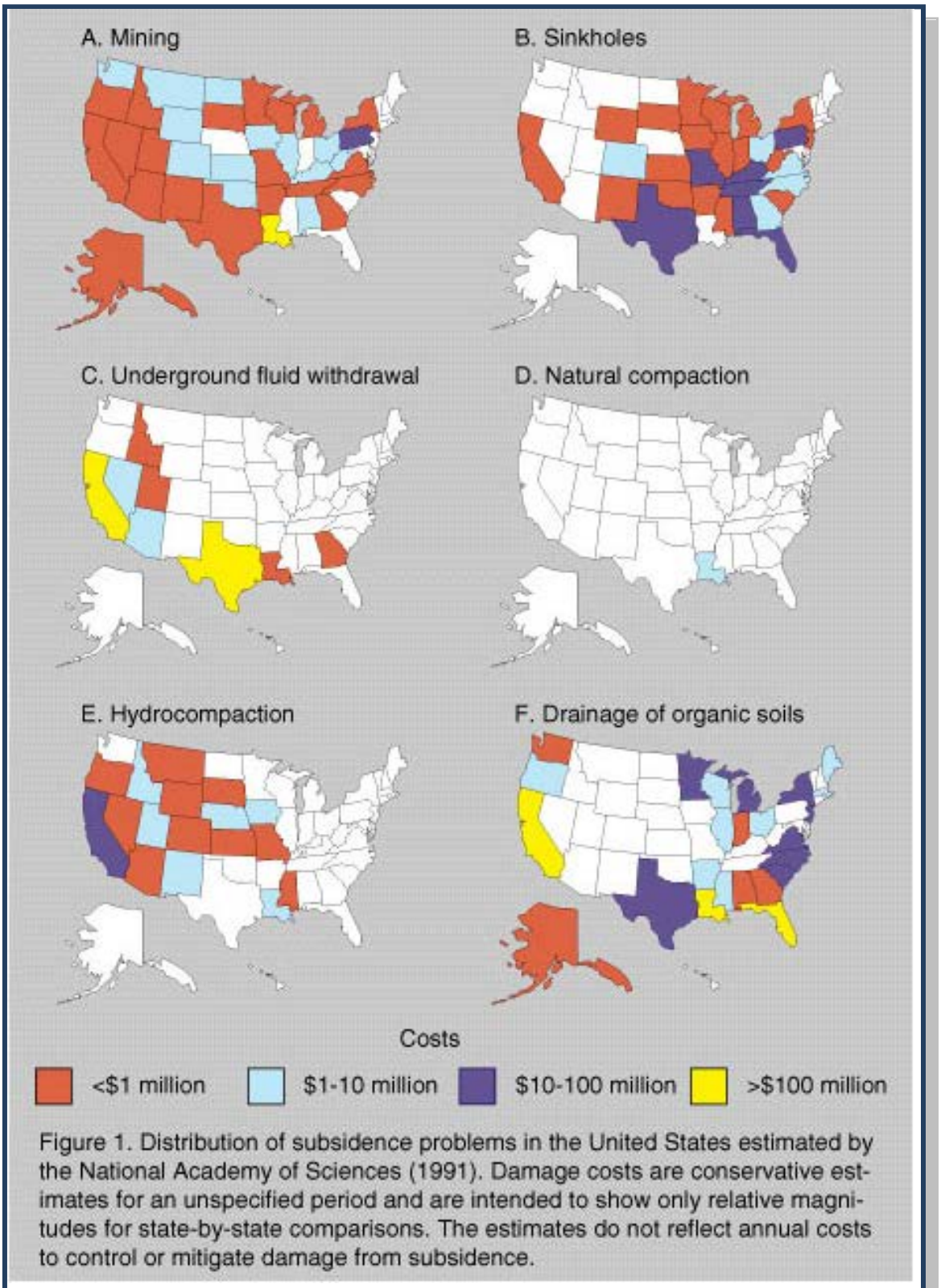


Figure 1. Distribution of subsidence problems in the United States estimated by the National Academy of Sciences (1991). Damage costs are conservative estimates for an unspecified period and are intended to show only relative magnitudes for state-by-state comparisons. The estimates do not reflect annual costs to control or mitigate damage from subsidence.

Subsidence problems in the United States (from Leake, 1997).

An earlier study noted that "Ideally, the development of sinkholes can be eliminated or minimized by ceasing the pumping that causes the decline of the water table. The cessation of or drastic decrease in sinkhole activity following a recovery of the water table has been recognized previously. Most efforts . . . have been directed toward measures minimizing sinkhole development and eliminating potential hazards and damage to structures rather than dealing with the cause" (Newton, 1984, p. 250).

Evidence of a subsidence fault on Highway 11 bridge. (photo from Lake Pontchartrain Basin Foundation).

Understanding and mapping land subsidence itself is usually only the first step. Gradual land subsidence subtly changes the land surface so the flood hazard changes. This is easy to imagine in a coastal situation: if the land is ten feet above sea level, and it subsides eleven feet, it will be below sea level.

It may be more difficult to envision the results of land subsidence at an inland location. Imagine a tabletop model of a river flowing through a broad valley. Now deform the land surface by placing a large bowl or sphere in the middle of the model and pushing it down just an inch or so. When the bowl is removed, the slope at the upper side of the depression is slightly greater, so water flows a little faster. Since the quantity of water is the same, if it is flowing faster, it will not be quite as deep.

However, at the lower side of the depression, the slope is slightly less, so the water will flow more slowly. The water level will be somewhat higher, and the area it covers will be somewhat larger. The deeper the depression, the larger the flooded area. This is what happens to relatively large areas where there is land subsidence. The floodplain gradually increases over time, and the flood elevation relative to the land surface gradually increases.


A sinkhole in Huntsville, Alabama (photo from Dr. Warren Campbell).

Subsidence increases the Frequency and Intensity of Flooding

Located along a low-lying coast that is subject to tropical storms, the Houston area is naturally vulnerable to flooding. In coastal areas, subsidence has increased the amount of land subject to the threat of tidal inundation. Flooding by tidal surges and heavy rains accompanying hurricanes may block evacuation routes many hours before the storms move inland, endangering inhabitants of islands and other coastal communities. The increased incidence of flooding in coastal areas eventually led to the growing public awareness of subsidence and its costs.

The fate of the Brownwood subdivision of Baytown affords a particularly dramatic example of the dangers of coastal subsidence. Brownwood was constructed, beginning in 1938, as an upper-income subdivision on wooded lots along Galveston Bay. At that time the area was generally 10 feet or less above sea level. By 1978 more than 8 feet of subsidence had occurred.

> The subdivision is on a small peninsula bordered by three bays. [It] is a community of about 500 single-unit family houses. Because of subsidence, a perimeter road was elevated in 1974 to allow ingress and egress during periods of normal high tide [about 16 inches], and to provide some protection during unusual high tide. Pumps were installed to remove excess rainfall from inside the leveed area. Because of subsidence after the roadway was elevated, tides of about [4 feet] will cause flow over the road. The United States Army Corps of Engineers studied methods to protect the subdivision from flooding. The cost of a levee system was estimated to be about $70 million. In 1974, the Army Corps estimated that it would cost about $16 million to purchase 442 homes, relocate 1,550 people, and convert [750 acres] of the peninsula into a park.
>
> This proposed solution was approved by the Congress of the United States and provided necessary funding. However, the project required that a local sponsor (the City of Baytown) should approve the project, provide 20 per cent of the funds ($3 million) and agree to maintain the park. By the time the first election to fund the project was held on 23 July 1979, the cost estimate had increased to $37.6 million, of which the local share was $7.6 million. The proposal was defeated, and two days later 12 inches of rain fell on Brownwood causing the flooding of 187 homes. Another bond election was held on 9 January 1980 and again the proposal was defeated. Accepting the residents' decision, Baytown officials began planning the sale of $3.5 million worth of bonds to finance the first stage of a fifteen-year, $6.5-million programme to upgrade utilities in the subdivision. Meanwhile, those who own the houses generally also owe mortgages and cannot afford to purchase other homes. Although they continue to live in the subdivision many have to evacuate their homes about three times each year (Gabrysch, 1983, p. 42).

The year that article was published, Hurricane Alicia struck a final blow to Brownwood. All homes in the subdivision were abandoned. Today, most of the subdivision is a swampy area well-suited for waterfowl; egrets and scarlet ibis are often seen (Galloway et al., 1999, p. 42).

Therefore, to really understand the flood hazards associated with land subsidence, it is necessary first to map historic land subsidence, then to project future land subsidence, and finally, to map the projected floodplain and future flood elevations.

Different causes of subsidence require different regulatory approaches for controlling the subsidence. For example,

- If land subsidence is a result of aquifer compaction, then changes in the amount of groundwater extracted and/or perhaps the location at which it is extracted, may be required to reduce or eliminate subsidence. This is a difficult choice to make when groundwater is needed to support existing and projected land uses. State or federal funding may be required to provide alternate sources of municipal, industrial, and agricultural water, and multiple jurisdictions may have to work together to control land subsidence.
- If land subsidence is due to the dewatering of organic soils, controlling the water table by extensive pumping may have to be combined with extensive levee systems if the land is to be used and the subsidence controlled.
- If land subsidence is caused by the dissolution of soluble subsurface materials, any subsurface movement of water makes the problem worse. Extraction or recharge of groundwater may accelerate the natural processes that cause sinkholes or more gradual land subsidence.

The local causes of land subsidence must be understood before regulatory standards can be applied. Where subsidence is gradual and ongoing, land use regulations may be effective in reducing flood damage. If the relatively constant rate of subsidence in an area is known, new development can be prohibited or elevated to compensate for predicted future subsidence. If the probability of subsidence (like sinkholes) is not uniform over an area, low density zoning may reduce the damage in the areas with highest risk. Again, the cause of land subsidence, combined with some ability to predict future subsidence, is required.

Hazards Related to Uncertain Flow Path Flooding

Uncertain flow path flooding includes alluvial fan flooding and hazards associated with moveable bed streams. These hazards differ from other flood hazards in that they usually include the added hazard of large quantities of moving debris and sediment, and the location and nature of the flood hazard changes continually over time.

The major uncertainty concerning moveable bed streams is how the stability of the channel changes over time. Throughout much of the arid and semi-arid regions of the United States, there is evidence that human activities over as short a time as a decade have drastically changed the nature of some streams. It is important to understand the causes of aggradation, degradation, and channel migration in order to project the future configuration of the channel.

Alluvial Fan Hazards

As defined in 44 *CFR* 59.1, "alluvial fan flooding" means flooding that occurs on the surface of an alluvial fan or similar landform, originates at the apex, and is characterized by high-velocity flows; active processes of erosion, sediment transport, and deposition; and unpredictable flowpaths.

FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix G: Guidance for Alluvial Fan Flooding Analyses and Mapping* (FEMA, 2003) generally addresses many of the issues raised in *Alluvial Fan Flooding* (National Research Council, 1996). "This appendix provides guidance for the identification and mapping of flood hazards occurring on alluvial fans, irrespective of the level of fan forming activity. The term **alluvial fan flooding** encompasses what will be described as **active alluvial fan flooding** and **inactive alluvial fan flooding**" (FEMA, 2003, p. G-1).

> Alluvial fans do not exhibit the more predictable behavior and well-defined boundaries normally found in most riverine floods. The behavior and path of floodwater in any individual event as it proceeds from the apex to the toe is a direct result of the flood processes previously illustrated. These processes vary as a function of the flow's sediment content and velocity, the fan's slope, soil and vegetative cover, and types and amount of fan development.
>
> Alluvial fan flows are subject to lateral migration and sudden relocation during the course of a flood, and may not even follow the same path in subsequent floods; in any flood event, however, a part of the fan will always be subject to flood hazards. Thus, it is generally not appropriate to utilize the location of past flow-paths in the prediction of future floods. The full range of hazards that occur on fan include:
>
> - High velocity flow (as high as 15–30 feet per second), producing significant hydrodynamic forces (pressure against buildings caused by the movement of flowing water)
> - Erosion/scour (to depths of several feet)
> - Deposition of sediment and debris (depths of 15–20 feet have been observed)
> - Debris flows/impact forces
> - Mudflows
> - Inundation, producing hydrostatic/buoyant forces (pressure against buildings caused by standing water)
> - Flash flooding (little, if any, warning time) (FEMA, 1989).

Alluvial fan extending from the Panamint Mountains in the background to the floor of Death Valley in the foreground (Miller, 2005, p. 18).

Management of flood hazards on alluvial fans requires more than knowledge of the existence and extent of the fans. The management techniques used at a particular location on a particular fan should be appropriate for the hazards (depth, velocity, and sediment and debris load) at that location. Within a small area, such as a county, fans may be similar enough to manage under a single set of standards, but these standards must be carefully developed.

Neither *Alluvial Fan Flooding* (National Research Council, 1996) nor *Guidelines and Specifications for Flood Hazard Partners, Appendix G: Guidance for Alluvial Fan Flooding Analyses* (FEMA, 2003) suggests much in the way of regulatory standards. In a discussion of several specific alluvial fans, the former has recommendations such as "avoidance of the hazard" and "only major structural controls will be effective because development is along the entire lower portion of the active fan."

Mitigation of flood hazards on alluvial fans must respond to three components of the hazard: velocity of the water, sediment, and debris; the volume and movement of sediment and debris during floods; and the potential for channel migration across the fan during flood episodes (avulsions). All of these components are present where there are no confined channels. Where there are confined channels, only the first two components of the flood hazard exist.

Streams with Migrating, Aggrading, and Degrading Channels

For the purposes of this discussion, areas subject to uncertain flow paths include streams where erosion (degradation of the streambed), sedimentation (aggradation of the streambed), channel migration, or combinations of these processes cause sufficient changes in the topography of the stream and/or its floodplain to affect the flood elevation or the location of the floodplain or floodway. In some locations, these processes may occur simultaneously, or one process may occur in one event while another process occurs in a subsequent event.

All of the floodplains in the world are formed by the erosion of mountains and the deposition of eroded material. There is an equilibrium among the rainfall, the sediment source, the slope of the watershed, and the slope of the floodplain. The equilibrium is different for each stream, but there are regional similarities and differences. These differences may require different approaches to mapping and management of their floodplains.

Sedimentation and erosion make traditional methods of mapping and management of flood hazards less reliable. Some stream reaches aggrade, some degrade, and in some reaches, the channels change their course, even from one flood to the next.

Migrating Channels

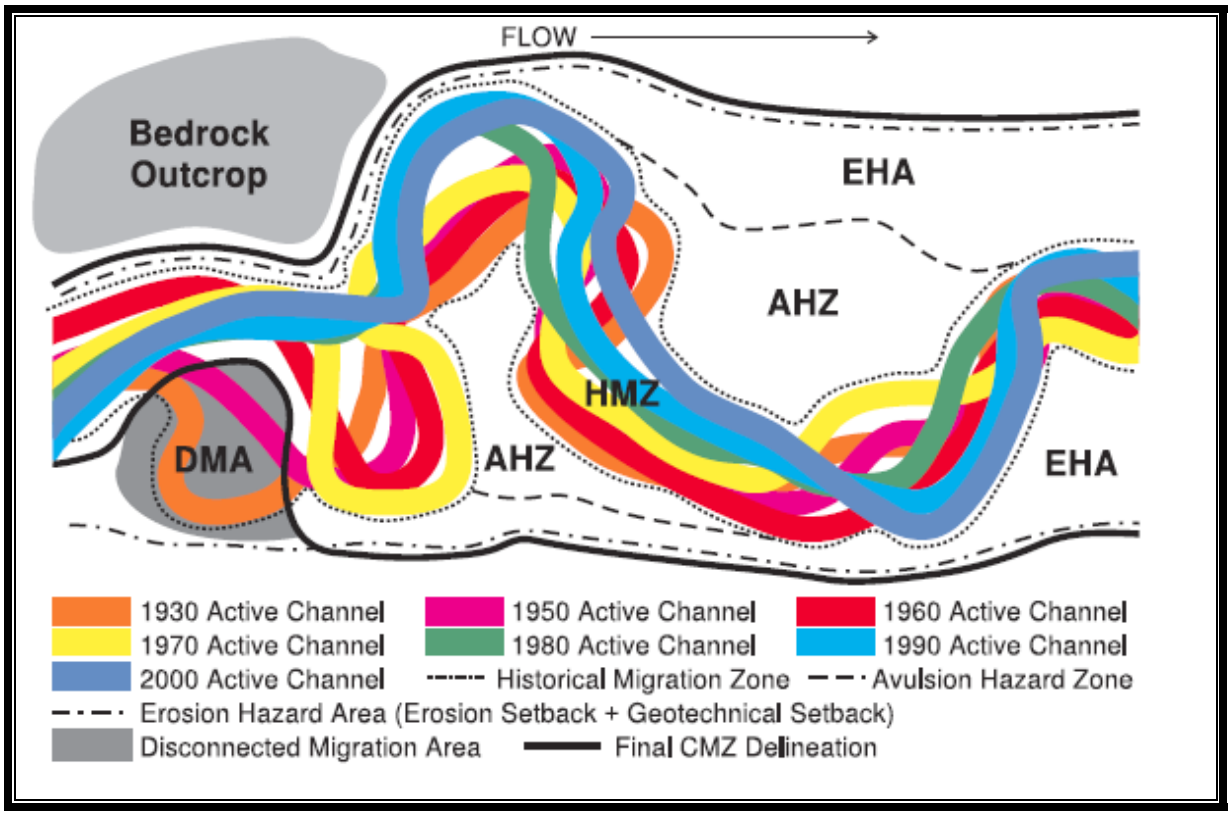
Dynamic physical stream processes can cause channels to move or "migrate" over time. The area within which a river channel is likely to move over a period of time is referred to as the channel migration zone (CMZ). Channel migration is a severe hazard that converts normally dry ground to a river bed, often by undercutting and destroying buildings, roads, and infrastructure. The hydraulic models approved in *Guidelines and Specifications* do not reflect possible changes in the channel bed during floods.

Keeping inappropriate development out of the CMZ will prevent flood-related damage such as this. – Packwood, Washington, Marvin Nauman/FEMA photo (1-10-07)

Region X recently published "*Floodplain Management and the Endangered Species Act, A Model Ordinance*" which uses the term "channel migration area." This term is defined as the mapped CMZ plus 50 feet and is the area subject to the regulatory requirements of the ordinance. *Regional Guidance for Hydrologic and Hydraulic Studies* was previously published to deal with the hydrologic and hydraulic aspects of mapping the CMZ. Once the CMZ is mapped, the area subject to regulations can be quickly delineated.

Although a CMZ does not account for dynamic changes in the channel bed during floods, it does delineate areas subject to the hazard. The CMZ is not mapped as part of a Flood Insurance Study and is not included on Flood Insurance Rate Maps (FIRMs), but it is appropriate to include within a community's mapping database and then regulate.

The State of Washington has published guidelines on the determination of channel migration zones (Rapp and Abbe, 2003). Zones determined with these methods have been declared critical habitat for endangered salmon by the National Marine Fisheries Service (2008) and now receive additional protection. Below is an example of CMZ elements.



Example figure of Channel Migration Zone elements: Historical Migration Zone (HMZ), Avulsion Hazard Zone (AHZ), Erosion Hazard Area (EHA) and the Disconnected Migration Area DMA (Rapp and Abbe, 2003).

CRS CREDIT FOR SPECIAL FLOOD RELATED HAZARDS

The hazards associated with ice jam flooding, flooding adjacent to closed basin lakes, mudflow hazards, flooding affected by land subsidence, and uncertain flow path flooding must be dealt with at the community level using all of the available tools used for floodplain management. Under the CRS, these tools are organized under four series of credited activities:

- Informing the public and specific populations, such as developers and engineers, about the hazards (300 series);
- Mapping and regulation of the hazard areas with recognition of the unique problems associated with the hazards (400 series);
- Special structural and nonstructural efforts to solve existing problems (500 series); and
- Special emergency preparedness efforts that recognize the particular problems associated with these hazards (600 series).

This section reviews the proven mitigation measures for the five special flood-related hazards addressed in this publication. In some cases, CRS credit is provided for an activity in the *CRS Coordinator's Manual*. In other cases, particularly in the 400 series, special credit is provided in this publication. For those credits, this document is a supplement to the *Coordinator's Manual* and the same formatting is used. The special flood-related hazard credit points calculated under this publication are transferred to the regular credit points in the *Coordinator's Manual*.

Just as riverine and coastal flood hazards require different mapping and management techniques, these special flood-related hazards require different techniques as well. This does not require a different or separate department in local government, just an additional set of standards that recognizes the features of these flood hazards and the appropriate use of the public information, engineering, planning, and other staff.

A number of CRS activities have credit for the special flood-related hazards discussed in this publication. However, a community's natural hazard management program should include other activities that do not receive CRS credit. For example, post-disaster recovery and mitigation policies might require damaged areas to be redeveloped with new street patterns to accommodate the clustering of structures away from high hazard areas.

On the next few pages are some fictitious examples of communities with areas subject to these special flood-related hazards. Note that in each case, special techniques are used to map the hazards, and special regulatory requirements have been adopted to mitigate them.

The first fictitious example shows why and how a local government might develop a program to deal with ice jam hazards and how the CRS would recognize its efforts.

Example 100IJ.

North County is generally hilly, with the North River running generally south to north through the center of the county. North City, the main population center in the county, lies on both sides of the North River near the center of the county.

The North River has a history of ice jams both near the northern edge of the county, where there is virtually no development, and within North City. Ice jams in North City have caused flood damage in the adjacent county.

The 2003 Flood Insurance Study for North County and North City used gage data for the North River to determine the base flood and the base flood elevation (BFE). Since then, three ice jam floods have caused higher flood elevations than the BFE in North City, and two caused higher flood elevations in the county. After the 2005 floods in the upper Midwest, North County requested a restudy of the North River. FEMA agreed to do a county-wide restudy.

The restudy developed new hydrology for the North River based on gage data that included the 2005 flood. The study contractor was also instructed to do a separate analysis for flood elevations under ice jam conditions. The resulting base flood based on the gage data has a peak flow about 15% larger than the flow used in the 2003 study. The resulting BFE was the same as the 50-year elevation from ice jam flooding in and upstream from North City. An ice jam analysis was also done for the undeveloped area near the northern edge of the county. Again, the new BFE based on clear water flooding was the same as the elevation of the 50-year ice jam flood.

For the reaches of North River that have experienced ice jam flooding, North County established a regulatory requirement that every new building in the Special Flood Hazard Area (SFHA) must have an engineering analysis of its foundation to ensure that it is safe from moving ice at the ice jam flood elevation, which is three feet higher than the BFE. They also prohibited development in the floodway of the North River in those reaches. The county also established zoning with a minimum lot size of 5 acres for the area near the northern edge of the county.

North County had joined the CRS after the 2005 flood as a Class 9 community. In 2010, when its revised FIRM was adopted along with its higher regulatory standards for areas subject to ice jam hazards, it improved to Class 8. The county received considerable credit for preservation of open space (Activity 420) because of its prohibition on development in floodways where there is an ice jam hazard. In Activity 430, the county received CRS credit for its foundation requirements in areas subject to ice jam hazards, and for low density zoning. Because FEMA provided the study delineating the ice jam hazard, the county received no credit in Activity 410.

Lake City is a fictitious county in the upper Midwest. The following example shows why and how a community might develop a program to deal with closed basin lake hazards.

Example 100CB.

Lake City is a growing city of about 60,000 people located on the east end of Glacial Lake. Glacial Lake is about 10 miles long from east to west and about 3 miles across at its widest point. There are small resorts and residences around the lake. Almost all of the land around the lake is owned by a paper company, and these resorts and residences are on land leased from the company.

Glacial Lake is a closed basin lake. Sporadic records have been kept of lake levels for a long time. A trading post built in 1810 atop a rock outcrop was flooded and abandoned in 1825. Farms were established in the area in the 1840s, and several farmers kept records of high and low lake levels until the farms failed because of a drought in the late 1870s. At that time, a lumber company began acquiring the homesteads at tax sales. In 1898, Lake City was established as a mill town. Since World War II, the area has attracted summer vacationers, and the lumber mill has been replaced by a paper mill. The paper mill and tourism are now of about equal importance to Lake City, and tourism and retirement appear to be the economic future of the area.

The water level in Glacial Lake began rising in 1995, and by 2000, buildings all around the lake had been flooded. Lake City asked the U.S. Army Corps of Engineers to study the problem and develop a project to deal with it. The Corps determined that

- Lake levels have varied from about 976 feet to 1,010 feet above mean sea level (msl) since 1810.
- The natural outlet from the lake is at 1,015 feet msl.
- The buildings flooded in 2000 were built between 1,000 feet and 1,005 feet msl.
- Lake levels never reached 1,000 feet msl between the drought in the 1870s and 2000.
- The City's FIRM was based on a lake level of 1,001 feet msl.
- The lake has probably not had an elevation above 1,005 feet msl since 1825, when the trading post was flooded.
- Winds from the west during the spring, when lake levels are highest, raise the lake level at Lake City about 6 inches (windset), and cause 18-inch waves.
- No structural project would provide protection from the highest potential lake elevations.

Lake City and the paper company discussed this situation and decided to work together to solve the flood problem. In 2000, Lake City had two miles of lakefront. There were 510 buildings in the City at an elevation below 1,012 feet msl. The area of the City that was below 1,012 feet msl was about 200 feet wide and included 50.8 acres. The paper mill, the downtown area, and the mall on the highway were all above 1,012 feet msl.

The paper company had a 160-acre lakefront parcel that had been used as a dump by the lumber mill and the paper mill from 1898 until 1975. This parcel abutted the City on its south side. Although the site was not especially hazardous, it was a U.S. Environmental Protection Agency (EPA) superfund site because runoff from the site degraded the water quality of the lake. The company ceded this land to the City.

In 2002, the City adopted a master plan to relocate all buildings below 1,010 feet msl to the superfund site, which was named Glacial Lake Park. Ninety-eight acres of Glacial Lake Park are above 1,012 feet msl. The City prohibited new buildings on land lower than 1,010 feet and required new buildings on land between 1,010 feet and 1,012 feet to be elevated to 1012 msl with floodproofed utilities. They stated that 1,010 feet msl was the BFE for Glacial Lake, and that they added 2 feet of freeboard to account for windset and wave action.

From 2002 through 2004, the City secured funds from EPA, the Corps, and FEMA to clean up the site. The citizens voted bonds to install streets and utilities as the area developed. The City offered free lots to lakefront residents who would relocate from their floodprone houses to Glacial Lake Park and deed their property to the City. By 2005, 102 buildings had either been moved to the Park or demolished. When the lake rose to 1,007 feet msl in 2009, 396 buildings were moved or demolished. The remaining 12 buildings were on land above 1,010 feet. Six of these buildings were already above 1,012 feet and the others were raised to that elevation. The 2009 relocations were facilitated by NFIP funds, including payments under Increased Cost of Compliance coverage, a grant from the Corps, and funds from the state.

By 2010, the City had converted 48 acres of the abandoned area to a City park.

Lake City had been too busy solving its flood problems to join the CRS until 2010. When it joined the CRS in 2010, it was rated a Class 6 community.

Steep County is a fictitious county in the West. The following example is intended to show why and how a community might develop a program to deal with mudflow hazards.

Example 100MF.

The western half of Steep County is a broad, relatively level river valley. The eastern half is foothills and mountains. Historically, more than 90% of Steep County's population lived in the valley, but in recent decades, more people are moving into the canyons in the foothills, and the year-round recreational amenities in the higher mountains have led to the development of large resorts and condominium complexes almost all the way to the tops of the mountains.

In the valley, floodplain management had been dealing with the problems associated with uncertain flow path flood hazards. During the 1990s, sediment transport modeling was used to delineate the floodplains for streams flowing from the mountains to the large river to the west.

In 1998, a different hazard became important to Steep County. Unusually heavy snows during the late winter, combined with a warm rainstorm in the early spring caused near-record flooding in the valley, but it also caused numerous landslides and mudflows in the foothills and mountains. The mudflows destroyed a considerable amount of new development and killed 12 people.

Steep County immediately contacted the State Department of Mining and Geology (DMG). DMG did a reconnaissance study that showed that there were numerous areas in both the foothills and farther up in the mountains that showed historic signs of landslide activity, and that recent development and road building had increased the probability of future landslides.

Steep County contracted with DMG to map the geologic hazards in western Steep County. The maps were completed in 2000. After three months of public hearings, Steep County adopted the DMG maps and a geologic hazards regulation. In some areas, the regulation prohibits development, and in other areas, it requires engineering and geologic studies before development, road building, or clearing or disturbing the surface.

In 2001, Steep County updated its comprehensive plan. The CRS planning process was used to receive CRS credit in Activity 510, and the geologic hazards maps and regulations were included in the plan.

Throughout the process of developing the geologic hazards maps and regulations and the development of the comprehensive plan, Steep County had mounted a public

information campaign on landslide and mudflow hazards in the foothills and in the mountains.

As a result of the comprehensive plan, the County adopted regulations requiring two feet of freeboard above the BFE for all watercourses with slopes greater than 5%. This provision allows for the sudden accumulation of sediment in channels downstream from landslides and mudflows. When a landslide occurs, it typically flows down a steep slope into a channel with a much shallower slope. The soil and rocks stop, raising the flood elevation. Subsequent flows erode the material away and carry it downstream. The freeboard was intended to provide protection during this process.

Because of these actions and other efforts of the Steep County staff, the County received CRS credit for Activities 330 (Outreach Projects), 340 (Hazard Disclosure), 350 (Flood Hazard Information), 360 (Flood Protection Assistance), 410 (Floodplain Mapping), 420 (Open Space Preservation), 430 (Higher Regulatory Standards), 440 (Flood Data Maintenance), and 510 (Floodplain Management Planning).

These activities improved Steep County's CRS class to 6, meaning that buildings in the floodplains shown on the FIRM receive a 20% discount on their NFIP premiums, and buildings outside the SFHA receive a 10% discount.

Flat County is a fictitious county in the West. Its experience shows why and how a community might develop a program to deal with land subsidence hazards.

Example 100SU.

The central portion of Flat County is a broad, relatively level river valley. The north and south portions of the County are arid mountains with rocky terrain and virtually no reliable water supply. Flat County was settled by the descendants of Europeans who moved into the area from the eastern United States in the mid to late 1800s. They ranched and developed limited agriculture with the available surface water from the Flat River. Agriculture increased dramatically with the introduction of the windmill, and by the mid 1900s the entire central portion of the County had been irrigated by groundwater pumped from ever-increasing depths.

By the 1990s, three things were becoming apparent. First, traditional kinds of agriculture were becoming uneconomical because of the energy costs for raising water 600 to 700 feet with pumps. Second, the cost of maintaining infrastructure was increasing due to land subsidence. Farms had to be re-leveled to irrigate properly. Ditches had to be replaced with pipes because they no longer had a slope appropriate to carry water.

Roads, gas pipelines, and other infrastructure were also requiring more repairs. Finally, floods on the Flat River in the 1990s flooded areas three or four times as wide as the SFHAs shown on FIRMs produced in the late 1970s.

The state geological survey studied Flat County and determined that there had been up to 20 feet of subsidence near the center of the county, immediately adjacent to the Flat River. The average slope of the Flat River through Flat County is 7 feet per mile, but land subsidence had increased the slope to about 9 feet per mile upstream from the center of the subsidence area and decreased the slope to about 5 feet per mile for a 10-mile reach downstream from the center of subsidence. This change in slope caused the channel to downcut in the steeper reach and caused sedimentation in the flatter reach. In the flatter reach, the combination of the lessened slope and the sedimentation resulted in a much wider floodplain.

In 1996, Flat County had a reconnaissance study done to find alternative solutions to the problems of subsidence and flooding. This study concluded that there was no feasible way to reverse the subsidence. It was estimated that if all groundwater pumping ceased immediately, subsidence would continue for another five years, and the maximum amount of subsidence would be about 25 feet. If groundwater pumping continued at the current rate, water would become uneconomical for agriculture in about 10 years, and the ultimate subsidence would be about 30 feet. There were no alternatives for the flood problem except to map and regulate a wider, and widening, floodplain.

After working with the local agriculture interests for two years, in 1998 Flat County secured state and federal funds to acquire the water rights for about 90% of the farm land. The landowners would be allowed to use the land for urban development, which requires only about 7% of the water used for irrigated agriculture.

In 1999, Flat County finalized a long-range comprehensive plan. This plan assumed that the remaining 10% of the farmland would become uneconomical to irrigate by 2010. It also assumed 10% annual population growth through 2010 and 5% annual growth from 2010 through 2020. A hydrogeologic study estimated that subsidence would end in 2030, with a maximum subsidence of about 27 feet. The comprehensive plan included a surface water model that estimated the runoff from development through 2030 as well as the maximum subsidence. Floodplain maps were made based on these conditions. Within the entire area subject to subsidence, the county adopted a special building code provision to require foundations that will resist damage due to subsidence.

Beginning with the results of the reconnaissance study in 1996, Flat County had mounted a public information campaign explaining the nature and the cause of the subsidence problem and the related flood problems. In 1998, it placed a temporary moratorium on development of any land that had been flooded

in the big flood of 1995. By 1999, when its comprehensive plan was adopted, it was able to combine local, state, and federal funds to buy conservation easements and offer density trades to preserve about 75% of the floodplain based on 2030 hydrology and subsidence.

Flat County joined the CRS after the 1995 flood. By 2001, it was a Class 8 community. When it adopted the comprehensive plan in 2001, it became a Class 5 community. It receives near maximum credit for all of the public information activities (the 300 series). It received credit for the mapping of the Flat River floodplain and additional credit because it is a special flood-related hazard area (Activity 410). It received credit for preservation of open space (Activity 420), and additional credit because it is in a special flood-related hazard area. It also received credit under Activity 430 for foundation protection and land development criteria. Its entire floodplain was entered into a geographic information system (GIS), and it set up a program to obtain new topographic maps every three years using LiDAR. It established a program to resurvey its benchmarks every year (Activity 440).

The comprehensive plan received almost the maximum credit for both stormwater master planning (Activity 450) and floodplain management planning (Activity 510). Because the County had been almost entirely agricultural in 1996, there were only 37 residences in the entire floodplain. By 1999, it had obtained grants from FEMA and the Nature Conservancy to purchase and demolish 20 of these homes (Activity 520).

Arid County is also a fictitious county in the arid West. The following example shows why and how a community might develop a program to deal with uncertain flow path flood hazards and how the CRS would recognize that effort.

Example 100UF.

The northeast part of Arid County, the Oriental Fan, is subject to alluvial fan flooding where runoff from the mountains flows onto the desert floor.

In the western part of the County, two rivers are subject to uncertain flow path flooding.

West River is a perennial stream that carries a heavy sediment load during floods. It flows in a broad sandy-bottomed gorge. The 100-year floodplain just covers the half-mile-wide bottom of the gorge, and the floodway shown on Arid County's Flood Insurance Rate Map (FIRM) averages 300 feet in width.

Dry Creek is a degrading stream for most of its reach in Arid County. Intense development in the upper parts of the Dry

Creek watershed since 1950 has caused an estimated 400% increase in the runoff from a 100-year storm. The channel has become incised, velocities have increased and scour is occurring in most reaches within the County.

In 1985, the Arid County Flood Control District did a study of the Oriental Fan area. Although the report indicated that the floodplains shown on the County's FIRM did not accurately reflect the flood hazard in the area, the Board of Supervisors declined to adopt stricter regulations.

In 1987, the Flood Control District completed studies on West River and Dry Creek. They were able to use the County's existing regulations to control development to avoid the worst of the hazards in those areas.

In 1997, a 50- to 100-year storm hit the mountains above the Oriental Fan and the fan itself. More than 100 residences were destroyed by erosion or by sediment and debris that hit the structures. An additional 27 suffered substantial damage and 300 more were damaged to a lesser degree. Flood depths were less than 3 feet in the affected areas, and the flood was gone 6 hours after it began. Most of the damage occurred outside the SFHA shown on the FIRM. Damage to County and private infrastructure exceeded the damage to structures.

Within a week of the Oriental Fan flood, the County Board of Supervisors instructed the Flood Control District to contract for a comprehensive hazard mitigation plan. The District is responsible for the County's floodplain management, stormwater management, and flood warning system. It is also the coordinating agency for the community's participation in the CRS.

The comprehensive plan was produced in a way that would get maximum CRS credit for Activity 510 (Floodplain Management Planning). The contractor reviewed the County's Flood Insurance Study, the studies of Oriental Fan, West River, Dry Creek, and numerous other studies conducted by the Flood Control District, the Corps of Engineers, the U.S. Geological Survey, and others. Among other things, they reviewed all flood hazards, alluvial fan hazards, and all moveable bed hazards in the County.

As a result of the hazard mitigation plan, the County adopted development regulations for the Oriental fan area, West River, and Dry Creek, and adopted the maps produced by the Flood Control District in the 1980s. The regulations included a county-wide requirement for retention of stormwater runoff. The Flood Control District also implemented a public information strategy to inform its residents about the County's special flood-related hazard areas.

Pierce County is an actual county in western Washington. For many years now they have had a program to deal with channel migration zones.

Example 200UF.

The Puyallup River and the Carbon River, a major tributary to the Puyallup, both have their headwaters on the slopes of Mt. Rainier. Both rivers carry a heavy load of sediment, and are subject to frequent flooding. From the website:

Pierce County regulates Channel Migration Zones as defined in Pierce County Code (18E.70). By 2012 channel migration zones had been mapped and adopted for the Puyallup, Carbon and White Rivers. County Code identifies additional rivers to be studied for CMZ hazards. These additional studies must be adopted by Council action before being used to make regulatory decisions. In 2007, studies were completed for the upper Nisqually River and for portions of South Prairie Creek. These studies are currently being reviewed for adoption.
http://www.co.pierce.wa.us/ArchiveCenter/ViewFile/Item/1162

Because the county has completed the mapping and uses the mapping for regulation it is now eligible for credit under 410SH and 430SH. In addition, since much of the area also qualifies for open space credit, the county can obtain credit under 420SH.

300 Public Information Activities

Because the flood hazards associated with the special flood-related hazards differ from "normal" flood hazards, there are special needs for public education. Property owners and developers must be made aware of the hazards and the methods needed to mitigate them.

When a state or local government has mapped special flood-related hazard areas, information identifying these areas and how to protect oneself from them should be automatically included in the community's Program for Public Information (PPI). Likewise, when higher regulatory standards for development in these areas have been adopted, these standards should be included in local public information and education programs.

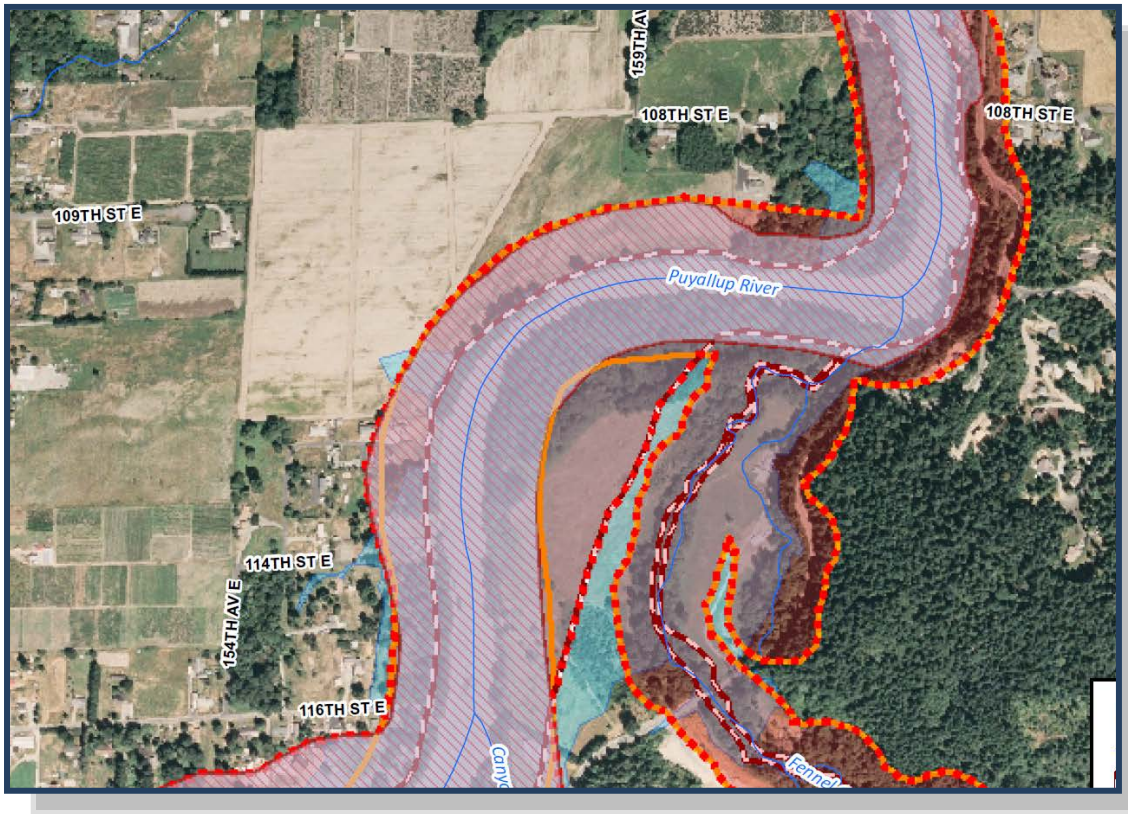
310 Elevation Certificates

There is no additional CRS credit for Elevation Certificates in areas of special flood-related hazards. FEMA Elevation Certificates, which are required for the purchase of NFIP flood insurance, and which must be maintained by CRS communities, MUST be based upon the current FIRM for the community, and they must be completed using the flood information from the FIRM and the corresponding Flood Insurance Study. There is no requirement to maintain Elevation Certificates outside the SFHA.

That means that if a community has mapped an area of alluvial fan flooding or an aggrading or migrating channel, and it is regulating areas outside the SFHA, and/or the regulatory flood elevation is higher than that shown on the FIRM, everyone must still use the data from the FIRM for the purpose of filling out the Elevation Certificate.

320 Map Information

Many communities provide inquirers with flood information from the Flood Insurance Study and FIRM. Some use this opportunity to explain local regulations, including the coastal erosion setback standards. This provides the inquirers with a more complete picture of the local coastal hazard and the importance of regulations in protecting property.



A portion of Pierce County's channel migration zone mapping (FEMA Region 10, 2012).
Map by Pierce County and GeoEngineers; air photo from U.S. Department of Agriculture
http://www.fema.gov/pdf/about/regions/regionx/nfip_esa_faq/nfip_esa_model_ordinance_final.pdf

If the community is receiving CRS credit for mapping and regulating its special flood-related hazards, the map information service should include telling inquirers if the property in question is mapped as a special flood-related hazard area. With the 2013 *CRS Coordinator's Manual*, there is dedicated credit for this, MI5. In order to obtain this credit, the community must also disclose any extra regulatory requirements for developing the property. This can help property owners and potential buyers better understand the natural hazards risks of a particular location. Understanding these risks can help property owners and builders identify and evaluate potential property protection measures.

330 Outreach Projects

This activity provides credit for newsletters, mailings, presentations, booths, brochures, and a host of other means of getting the word out to the public or target audiences, such as builders or school children. Credit is for conveying information on topics selected by the community. These topics should include information on the special flood-related hazards, in addition to the flood hazard mapped on the FIRM.

If the community develops a PPI, it can receive additional credit for additional topics related to the special flood-related hazard.

340 Flood Hazard Disclosure

The CRS provides credit when real estate agents disclose information about a property's flood hazard to prospective buyers. More credit is provided if the disclosure includes other hazards, such as special flood-related hazards. State or local mandates for sellers, landlords, or developers to disclose these hazards can receive credit. If real estate agents don't actually disclose a property's hazards, but provide a handout advising house hunters about what to look for and what questions to ask, additional points are provided.

350 Flood Protection Information

Under Activity 350, communities receive credit for putting flood protection information in their public libraries and on their websites. These materials should cover all known flood-related hazards, including special flood-related hazards. Additional credit points are provided if the library has locally pertinent references, such as studies or reports on its local hazards. The community or the librarian should also review the references at the end of this supplement to identify additional documents that would be helpful locally.

Some of the websites mentioned in this publication could also be good links for the community's website coverage of its special flood-related hazards and ways people can protect themselves and their property.

Example.

Arid County has several publications on alluvial fans in its library, including *Alluvial Fan Flooding*, by the National Research Council. Its website includes several pages on alluvial fan flooding and channel migration, along with an explanation of how the floodplain management ordinance protects new development from damage while enhancing the County's system of linear parks and trails.

360 Flood Protection Assistance

Floodplain residents are more likely to undertake activities to reduce the risks from special flood-related hazards to their property if reliable information is available locally. The CRS provides credit if a local government provides technical advice to interested property owners and publicizes that this service is available.

A community that is offering assistance and receiving credit for Activity 360 should have its staff trained about protection measures appropriate for the local hazards.

Example.

Upon requests from property owners, an Arid County staff member will make visits to properties to explain the requirements of its floodplain management ordinance and to help the property owners locate their structures on their property if it is in a delineated alluvial fan, or if it is within a setback area.

370 Flood Insurance Promotion

Floodplain residents are more likely to purchase insurance to cover their potential losses from special flood-related hazards to their property if they are aware it is available and if reliable information on cost and availability is provided locally. The CRS provides credit if a local government has a plan for promoting flood insurance, provides technical advice to interested property owners, and implements the plan.

That local plan should review what types of insurance will provide coverage for the different hazards. For example, an NFIP flood insurance policy may not cover structural damage due to slowly settling land in an area subject to subsidence or damage to a building that falls into a channel that migrated when there was no flood.

400 Mapping and Regulations

FEMA and many communities have long recognized that the mapping and/or minimum regulatory standards of the NFIP do not adequately address the problems of special flood-related hazards. Since these special flood-related hazards have the potential for extraordinary flood damage, it is important that communities deal with the hazards in ways that go beyond the minimum NFIP standards.

To protect new development in areas subject to special flood-related hazards, a community must have maps that adequately define the hazards and ordinance language that deals with the specific hazards in those areas.

410SH Special Flood-related Hazard Area Mapping

NOTE: *This section is a supplement to Activity 410 (Mapping) in the* ***Coordinator's Manual****. Much of the discussion in this section relies on Activity 410. Please read that section before proceeding*

Mapping credit for ice jam hazards (MIJ) credit (up to 50 points) under Activity 410 is provided for communities that map and regulate areas with special flood-related hazards are discussed in this section. All special flood-related hazard credits are provided only if those areas are mapped by methods described in this section.

Credit Criteria

(1) Credit for mapping areas subject to special flood-related hazards is only given if the community receives at least 20 points under Section 420SH and Section 430SH combined.

(2) To receive credit for mapping, open space preservation, and/or management of special flood-related hazards, the community must map the hazard areas in detail, or the community must require developers to do so as a condition of any development permit. The mapping technique must be in conformance with *the Flood Insurance Study Guidelines and Specifications for Study Contractors*, http://www.fema.gov/library/viewRecord.do?id=2206, or for hazards without approved techniques listed in the Guidelines the techniques must be approved by the ISO/CRS Technical Reviewer. If the community prepares a new map it is also eligible for regular Activity 410 credit.

(3) To receive CRS credit for mapping, areas of land subsidence where subsidence is due to the formation of sinkholes, the maps must show all existing sinkholes in the community. To receive CRS credit for open space preservation and/or management of land subsidence where subsidence is due to the formation of sinkholes, the maps must include areas where there is a potential for new sinkholes using methods accepted by the ISO/CRS Technical Reviewer.

(4) In the case of aggrading or degrading streams, a sediment transport model is required that includes the availability of sediment to the stream, and that accounts for its movement through the floodplain. Modeling of these streams for CRS credit must look at present conditions and projections of future conditions based upon changes in the source of sediment and the floodplain. Mapping must be based upon the worst case of aggradation or degradation.

(5) In the case of channel migration, the local history of migration must be reflected in the mapping process. For full credit, mapping must be based upon floodplain soils and historic channel migration that indicate the probable extent of future migration.

(6) To receive CRS credit for mapping, the mapping must be adopted by the community and used for land use regulation to prevent damage from the special flood-related hazard.

Credit Points

a. Mapping ice jam hazards (MIJ) (Maximum credit: 50 points)

Mapping areas subject to ice jam hazards requires a hydrologic analysis of the stream reach that includes ice jam flooding. Although FEMA's *Flood Insurance Study Guidelines and Specifications for Study Contractors* specifies methods for analyzing ice jam floods, the hydrology typically done for flood insurance studies and most other types of studies is based on clear water flow.

Example 411IJ-1.

In 1996, the state mapped North County's floodplains based on new hydrology. The 100-year ice jam flood elevations based on historic ice jam flooding also were determined. North County is eligible for credit under Section 410SH because the state performed the mapping.

b. Mapping closed basin lakes (MCB) (Maximum credit: 50 points)

Mapping flooding due to closed basin lakes requires a hydrologic analysis of the watershed draining to the lake. Appendix C of FEMA's *Flood Insurance Study Guidelines and Specifications for Study Contractors* specifies methods for determining flood elevations for closed basin lakes.

c. Mapping mudflow hazards (MMF) (Maximum credit: 50 points)

(1) 50 points, for mapping mudflow or landslide hazards in areas outside the SFHA as shown on the community's FIRM if the scale of the mapping is 1:10,000 or smaller.

(2) 50 points, for mapping mudflow or landslide hazards in areas inside the SFHA as shown on the community's FIRM if the scale of the mapping is 1:10,000 or smaller and the regulatory flood elevation is higher than the base flood elevation shown on the FIRM.

(3) 20 points, for mapping mudflow or landslide hazards in areas outside the SFHA as shown on the community's FIRM if the scale of the mapping is larger than 1:10,000.

Mapping areas subject to mudflow hazards requires examining previous landslides, soils, and topography. No specific method is recommended for CRS credit. Maps from any source that are used by the community for regulatory purposes, as long as they are at an appropriate scale, are acceptable for CRS credit with approval from the ISO/CRS Technical Reviewer.

Example 411MF-1.

The state Department of Mining and Geology (DMG) mapped Steep County's mudflow hazards at a scale of 1" = 200' (1:2,400).

MMF = 50

Example 411SU.

In 1999, Flat County mapped the floodplain based on ultimate subsidence and development through the year 2030. At the same time, FEMA hired the County's consultant to map the floodplain under existing conditions. Flat County receives MSU1 = 50 for areas that were outside the SFHA on its 1978 FIRM. It receives MSU2 = 20 for areas that were within the SFHA on its 1978 FIRM.

d. Mapping areas subject to land subsidence (MSU) (Maximum credit: 50 points)

(1) 50 points, for mapping the area outside the SFHA shown on the community's FIRM that is subject to subsidence.

(2) 20 points, for mapping areas inside the SFHA as shown on the community's FIRM that are subject to subsidence.

Managing Subsidence in the Houston Area

The Harris-Galveston Coastal Subsidence District (District) was created in 1975 to regulate the withdrawal of groundwater within Harris and Galveston Counties. The District was created "…for the purpose of ending subsidence, which contributes to or precipitates flooding, inundation, or overflow of the district, including without limitation rising waters resulting from storms or hurricanes."

Since 1976, the District has adopted three regulatory plans. The initial plan focused on having an immediate impact in the area where the most subsidence had taken place and where surface water was available as an alternative to groundwater. The 1976 plan regulated pumpage in all of Galveston County and much of eastern Harris County in an area referred to as the "area of concentrated emphasis."

The 1985 plan divided the District into eight regulatory areas so that subsidence could be addressed throughout the entire District. This plan had an overall goal of changing primary water usage from groundwater to surface water through a series of steps.

The 1992 plan modified the 1985 plan based on a detailed re-analysis of regional population and water demand data. The 1992 plan divided the District into seven regulatory areas with goals for each area to reduce groundwater withdrawal by certain dates. The areas were based on surface water availability, geophysical characteristics, and groundwater demand.

The 1999 regulatory plan divides the District into three regulatory areas. The regulatory areas of this plan have been reconfigured from the 1992 plan to generally reflect converted versus unconverted areas. The requirements contained within the regulatory plan are based on the most current data and studies on water demand, aquifer levels, and projected subsidence, and provide permittees with organizational flexibility in meeting these regulations.

In the most critical areas (closest to the Gulf Coast), water users must limit groundwater use to 10% of their total water use. In the next most critical area, groundwater use is limited to 20% of total water use.

Even with these regulatory measures in effect, water levels declined as much as 100 feet during 2002, and land subsidence of up to one foot was measured. Rainfall was above average at most locations in the District (http://www.hgsubsidence.org/).

e. Mapping credit for uncertain flow path hazards (MUF) (Maximum credit: 50 points)

(1) MUF1: Credit of 50 points is provided for alluvial fan or moveable bed stream mapping.

(2) MUF2: Credit of 25 points is provided for the following requirements when there are no studies that meet the criteria for MUF1.

(a) In the case of aggrading or degrading streams, for permits for single structures the community may require only a statement from a registered professional engineer or licensed geologist that the proposed structure is reasonably safe from the erosion- or sediment-related flood hazard.

(b) In the case of channel migration, credit is provided if a community uses a locally developed standard building setback for unstudied streams in lieu of a detailed study by a developer. Such a setback standard must be based upon data from the general area regulated.

Example 411UF-1.

Arid County mapped the West River as a stream with a migrating channel and Dry Creek as a stream with a degrading channel. These studies were also adopted by the County Commission in 1997.

Arid County requests CRS credit for MUF2a and MUF2b.

Mapping7+ Alluvial Fans: Mapping of alluvial fans must be done in conformance with the *Guidelines for Determining Flood Hazards on Alluvial Fans* (FEMA, 2003), which prescribes methods for mapping alluvial fan hazards. When alluvial fan floodplain mapping is provided by FEMA, there is no Activity 410SH credit, but there may be regular Activity 410 credit if the community provides data for the study. Even when there is no CRS credit for mapping alluvial fan hazards, these hazards must be mapped before other CRS credit can be verified for management of these hazards. If the community prepares a new map that includes alluvial fans, it is eligible for regular Activity 410 credit.

Although the *Guidelines* prescribe mapping methods for alluvial fans, active support is generally needed by the community to get such mapping included on the community's FIRM. This is because alluvial fan mapping must generally be accompanied by specific ordinance language.

If a community has alluvial fan hazards, it should implement appropriate mapping and management of these hazards.

Mapping Degrading Stream Reaches: Mapping degrading stream reaches for management purposes is relatively simple. As the channel degrades, the inundated area shrinks until it is contained within the degraded channel. Unless the stream banks become unstable and the channel migrates, errors will generally be on the safe side, since the areal extent of the flood hazard is either stable or becoming smaller. There are no known maps used for floodplain management purposes that account for channel degradation, although local studies of degradation and scour have been performed in many communities.

The objective when mapping degrading stream reaches is to identify the location and progress of the degradation process so that facilities in and immediately adjacent to the channel can be designed to be safe from the ongoing degradation.

Mapping Aggrading Stream Reaches: In areas where aggradation is suspected or has occurred during historic flooding, it is expected that the channel is losing capacity, the floodplain is getting wider and flood elevations are getting higher. These are the problems to be addressed by mapping. The result may be similar to mapping floodplains based on future-condition hydrology for developing watersheds.

Mapping Reaches Subject to Channel Migration: In stream reaches where the channel may migrate, sometimes outside the 100-year floodplain as defined by fixed-bed modeling, the establishment of setbacks from the channel banks based on historic channel migration may take the place of more rigorous mapping techniques. This approach requires a developer to perform a detailed study of the channel morphology before developing inside the setback. Example techniques have been provided by the State of Washington, and can be accessed at http://www.ecy.wa.gov/biblio/0306027.html.

Example.

In King County, Washington, a mapping process similar to that proposed by the Washington Department of Ecology was used to map a migrating channel. In a study of the Green River, the effect of sediment transport throughout most of the reach was related to locations of channel migration, rather than ongoing aggradation or degradation. Delineation of "probable unconstrained limits of channel migration" was based primarily on historic data. The "mitigated hard area" was then delineated assuming that ongoing protection would be provided for major roads, subdivisions, and levees in the floodplain. Several counties in Washington have since used these techniques on their rivers.

Example.

Pima County, Arizona, applies a construction setback of 500 feet from the channel bank of specified major streams, 250 feet for streams where the 100-year flow is more than 10,000 cfs, 100 feet for streams with 100-year discharges greater than 2,000 cfs, and 50 feet for streams with 100-year discharges greater than 100 cfs (Cella Barr Associates, 1987). These setbacks are based on the experience of the Pima County Flood Control District. Pima County also used recent and historic aerial photos and old land survey notes to more precisely determine setback limits for the Rillito River in and near Tucson, Arizona. Exceptions are made where there is bedrock or other impediments to channel migration, where there is bank protection provided, or where an engineering study indicates that the channel will not migrate.

Example.

The State of Arizona developed a similar standardized approach that is applied statewide. It establishes a setback for all streams based on the 100-year flow, the curvature of the channel, and other parameters. This approach has been implemented by Arizona communities as a minimum standard.

Credit Documentation

The documentation must show how the mapping addresses the special flood-related hazard mapping criteria described in this section.

(1) The community must provide the following:

(a) A map that shows the areas subject to the special flood-related hazards and the other floodplains (including the SFHA) in the community. If only a small area of the community is mapped for special flood-related hazards, only the SFHA in that area need be shown on the map.

(b) A description of the method used for the mapping that shows that it reasonably delineates areas subject to the special flood-related hazards and provides sufficient documentation for the ISO/CRS Technical Reviewer to accept.

(c) Credit for 410SH is only provided if the mapping is used for land use regulation to prevent damage from the special flood-related hazard. The documentation required for 420SH or 430SH will suffice for this prerequisite.

Credit Calculation

cMAPSH = cMIJ + cMCB + cMMF + cMSU + cMUF

420SH Open Space Preservation in Special Flood-related Hazard Areas

NOTE: *This section is a supplement to Activity 420 (Open Space Preservation) in the* ***Coordinator's Manual****. Much of the discussion in this section relies on Activity 420. Please read that section before proceeding.*

One of the best ways to prevent flood damage is to keep floodprone areas free from development. In addition to the flood protection benefits, preserving open space can greatly enhance the natural and beneficial functions that floodplains serve. For CRS credit, "open space," means that the land must be free from buildings, pavement, fill, or other encroachments to flood flows.

In areas subject to special flood-related hazards, preservation of open space may be the single most important tool for protection of future development.

For example, there are two hazards associated with ice jam flooding: higher flood elevations when ice plugs the channel and/or floodplain; and the movement of ice floes. The elevation hazard can be mitigated by elevating or floodproofing buildings. The movement of ice floes may be difficult or impossible to mitigate with construction methods (see photo on page 3), and preservation of areas subject to this hazard as open space may be the only sure way to mitigate the hazard.

In areas adjacent to closed basin lakes, the primary cause of flood damage is the duration of flooding. There may be areas at the edge of this hazard that can be developed with special attention to access and utilities, but inside this area, preservation of open space may be the only viable means of mitigating the hazard.

Special flood-related hazard open space credit (SHOS) and low density development credit (SHLZ) are provided under Activity 420 for having floodprone property within a designated special flood-related hazard area preserved as publicly owned or controlled open space. This credit is in addition to the credit provided for open space (OS) in Activity 420.

All of the requirements of Activity 420 apply to 420SH credit. In addition, areas for which this credit is provided must be mapped as areas subject to special flood-related hazards as discussed in Section 410SH.

Land development criteria, such as clustering the buildings in a development to keep them out of the hazardous area, and low density zoning, which reduces the development potential in the area, can also reduce the damage potential. The credit for low density zoning is based upon the traditional zoning approach of setting minimum lot sizes for different zoning districts. The bigger the lot size, the less dense the development will be in the special flood-related hazard area**.**

Credit Criteria

(1) The area must be designated as an area subject to special flood-related hazards in a study that is credited under Activity 410SH.

(2) The area must be eligible for

   (a) Open space preservation; or

   (b) Low density zoning as discussed in Activity 420 in the *CRS Coordinator's Manual*.

Credit Points

SHOS = 100 points

SHLZ = up to 50 points for zoning regulations

s = minimum lot size (5 to 10)

SHLZ = s x 5 points

Example 421UF-1.

Arid County mapped 212 acres of the Oriental Fan as “Active Alluvial Fan Area” and prohibits structures and fill within those areas. These areas were not developed when the mapping was done. There is also a 565-acre County park preserve in the AO zone.

Because the prohibition of structures and fill in undeveloped areas of the Oriental Fan and West River qualify for credit for preservation of open space (OS) in Activity 420, both of these areas are eligible for UFOS credit.

This gives a total of 777 acres of open space in uncertain flow path hazard areas.

Impact Adjustment

Open space and low density zoning credits are adjusted based on the ratio of preserved open space areas in the area of special flood-related hazard (aSH) to the total aSH. Section 402 has additional information on impact adjustments for areas. The areas qualifying for SHOS or SHLZ need to be marked on the OSP Impact Adjustment Map.

$$rSHOS = \frac{aSHOS}{aSH}$$

$$rSHLZ = \frac{aSHLZ}{aSH}$$, where

aSHOS = the size of the area(s) of special flood-related hazard

aSHLZ = the size of the area(s) with low density zoning

aSH = the size of the community’s mapped special flood-related hazard area

Credit Documentation

(1) The community must provide the following:

(a) The community must receive credit under 410SH.

(b) Documentation that the area where open space credit is requested is in the special flood-related hazard area and meets the open space requirements of Activity 420 (Open Space Preservation) in the *Coordinator's Manual*.

(c) An Impact Adjustment Map prepared in accordance with Section 403 must be provided. Each area for which open space or low density zoning credit is being requested must be designated on the Impact Adjustment Map and in the map's key.

(d) The ordinance language that adopts the low density zoning standard.

(e) An explanation of the procedures followed for enforcement of the regulatory standard.

(f) For low density zoning, examples of developments constructed in accordance with the ordinance language.

Credit Calculation

cSHOS = (SHOS x rSHOS) + (LZSHs x rLZSHs), up to the maximum of 50 points

430SH Higher Regulatory Standards for Special Flood-related Hazards

NOTE: *This section is a supplement to Activity 430 (Higher Regulatory Standards) in the* ***Coordinator's Manual****. Much of the discussion in this section relies on Activity 430. Please read that section before proceeding.*

In areas where it is not feasible to restrict land to open space uses, other land use planning measures can be used to minimize flood damage. These include strategically controlling the type of development and uses allowed in hazard areas, and avoiding high-value and high-occupancy uses as much as possible.

Credit is provided for regulating special flood-related hazard areas in a manner that recognizes those elements of the hazard not addressed by the NFIP minimum standards for floodplain management. This credit is in addition to credit provided for other regulatory standards under Activity 430 in the *Coordinator's Manual*.

Credit Criteria

(1) The community must have received credit for mapping areas subject to special flood-related hazards under Section 410SH, except for ice jam hazards, closed basin lakes, or alluvial fan hazards, which may have been provided by FEMA.

(2) The community must adopt and enforce regulatory standards that address the special risks associated with these hazards.

Credit Points

a. Prohibition of buildings (SHDL2)

SHDL2 = 100 points for prohibition of buildings within the special flood-related hazard area

b. Ice jam regulations (IJR) (Maximum credit: 80 points)

1. IJR = the sum of the following: (a) 50 points, for requiring new structures to be constructed on engineered fill or engineered pilings at or above the ice jam regulatory flood elevation (b) 10 points x freeboard above the ice jam regulatory flood elevation (in feet) (maximum credit = 30 points for 3 feet of freeboard)

Regulation of areas subject to ice jam flood hazards should include protecting buildings from both the hazard from higher flood elevations and the hazard associated with moving ice floes. These regulations may include higher minimum floor elevations and structural requirements for buildings so that they are not damaged or destroyed by moving ice. There may also be special requirements for infrastructure in areas subject to ice jam hazards.

Example 431IJ.1.

North County prohibits development in the reach of the floodway affected by ice jam flooding. IJR1 = 50 + 14 = 64. In the reaches regulated for ice jam hazards outside the floodway, IJR2 = 50.

c. Closed basin lake hazard regulations (CBR) (Maximum credit: 80 points)

1. CBR = the sum of the following:

   (a) 40 points, if new structures are required to be built on fill at or above the regulatory flood elevation for closed basin lakes credited in 410SH

   (b) 10 points, if access is required at the regulatory flood elevation

   (c) 10 points, if all utilities are required to be protected to the regulatory flood elevation and functional during the regulatory event

   (d) 15 points, if all utilities and basements within 1,000 feet of the shoreline established by the regulatory flood elevation are required to be floodproofed to the regulatory flood elevation unless it can be demonstrated that the water table under the proposed development will not be affected by lake elevations

   (e) 5 points, if new wells constructed within the hazard area are required to be floodproofed to the regulatory flood elevation, and all existing wells that are to be abandoned are required to be sealed to eliminate the mixing of groundwater and lake water

CRS credit for regulation of areas subject to closed basin lake flood hazards should anticipate both the flood elevation and the long duration of high water surface elevations. It is important to protect utilities and infrastructure from long periods of inundation and to ensure access to buildings at the highest anticipated lake level. There is credit for land development criteria that reduce development adjacent to closed basin lakes, such as density trades, and for low density zoning in these areas.

Example 431CB.

Lake City requires buildings on land between 1,010 feet and 1,012 feet msl to be elevated on fill to 1,012 feet. No septic tanks or wells are allowed in areas where the land elevation is below 1,012. CBR = 45.

d. Mudflow hazard regulations (MFR) (Maximum credit: 35 points)

1. MFR = the sum of the following:

   (a) 25 points, if a study by a soils engineer and/or an engineering geologist is required for any hillside grading where stability will be lessened by the grading, and at historic or prehistoric mudflow and landslide sites

   (b) 5 points, if where buildings are to be supported on stilts over a fill slope with a slope greater than two horizontal to one vertical, footings must extend at least 3 feet into the underlying bedrock, but not less than the depth required to resist the lateral load

   (c) 5 points, if drainage from impervious surfaces must be collected and conducted to the street in a non-erosive manner

Maps of mudflow hazard areas are usually based on relatively large-scale map analysis, so most regulations require an engineering study, a geologic study, or both. The idea is that some of the area mapped as mudflow hazard may actually not have such a hazard, but it is the developer's responsibility to determine the true hazard.

e. Land subsidence regulations (SUR) (Maximum credit: 80 points)

1. SUR = the sum of the following:

   (a) Credit is provided for regulating development in the floodprone areas subject to land subsidence based upon the regulatory flood elevation, considering projected subsidence, as determined in accordance with the criteria of Section 411SH. Credit for SUR is the sum of (1) and (2):

      (1) 60 points, if all new buildings must be built on engineered foundations with pilings that will prevent the building from sinking as subsidence continues

      (2) 20 points, if all new public facilities and utilities are required to be designed for the subsidence hazard

   (b) If the community does not apply for regulation of development (SUR1) under the above section, credit is provided for activities intended to reduce future land subsidence. If the community has mapped current subsidence, and if that subsidence is greater than 1.0 foot, and if the community is implementing a scientific plan to reduce future subsidence, SUR2 = 40

Regulation of the activities that cause subsidence is the most direct approach to mitigating it. Techniques for preventing or controlling subsidence vary according to the type of subsidence. In the case of resource extraction, they range from banning extraction to controlling how materials are removed. For land development that causes subsidence, they range from banning development to regulating construction practices.

> "Worst case" for purposes of this element means the worst hazard over the period of the mapping study. If, for example, a stream is shown to be aggrading, the worst case might be a combination of unstable vertical banks today, requiring a setback, and a higher flood elevation in the future, requiring higher building elevations. In the case of a degrading channel, the worst case is the present flood elevation and future unstable banks or channel migration.

f. Uncertain flow path regulations (UFR). A community may receive credit for regulation of areas subject to four types of uncertain flow path hazards: alluvial fans, aggrading stream channels, degrading stream channels, and migrating stream channels. However, at any given area or stream reach, credit will be allowed for only one type of uncertain flow path hazard. For each stream reach or area, the community should seek credit for the one that gives the highest credit for UFR.

(1) Regulating development in areas subject to alluvial fan hazards (UFR1) (Maximum credit: 80 points).

UFR1 = the sum of the following:

(1) 60 points, if all new structures are required to be engineered to be protected from alluvial fan hazards

(2) 10 points, if all utilities are required to be designed to function and minimize damage during the 100-year event

(3) 10 points, if access is required during the 100-year event

---

(2) Regulating development in areas subject to moveable bed stream hazards (UFR2) (Maximum credit: 80 points).

Credit for the three types of moveable bed streams is mutually exclusive, and exclusive of alluvial fan areas. If the mapping process indicates that the nature of the stream changes over time (for example, the channel degrades for a period and then aggrades over another period), the community must demonstrate that its regulation addresses the "worst case" of flood hazard over the entire period.

(a) Aggrading stream regulations (UFR2) (Maximum credit: 80 points)

UFR2 = the sum of the following:

(1) 40 points, if all new structures are required to be elevated to the UFR2 flood elevation;

(2) 15 points, if new non-residential structures are required to be elevated or floodproofed to the UFR2 flood elevation

(3) 15 points, if public improvements and utilities are required to be protected from the UFR2 flood elevation

(4) 10 points, if protection is required to at least 1 foot above the UFR2 flood elevation. This credit is in addition to appropriate FRB credit in Activity 430

(b) Degrading stream regulations (UFR3) (Maximum credit: 80 points)

UFR3 = the sum of the following:

(1) 40 points, if new structures within 200 feet of the banks are required to have engineered foundations

(2) 40 points, if public improvements and utilities within the floodplain are required to be designed to withstand the worst-case base flood and channel conditions

(c) Channel migration regulations (UFR4) (Maximum credit: 80 points)

UFR4 = one of the following:

(a) 80 points, if a detailed study of the migration potential has been mapped, and if all public and private developments are prohibited within the zone; OR

(b) 65 points, if all public and private developments are required to be located and designed to be safe from channel migration; OR

(c) 40 points, if a standard setback is mapped, and all public and private development is permitted only after a detailed study of the channel migration hazard

Example.

Maricopa County, Arizona, has separate management schemes for “High Hazard,” “Uncertain Flow Distribution Area,” and “Approximate” alluvial fan areas. Development is required to be elevated two feet above grade. Alluvial fan areas are designated as “Administrative Floodways,” with management similar to that required by the NFIP for floodways.

From the “Floodplain Regulations for Maricopa County” as amended November 2011:

> Section 611. Zone A Alluvial Fan High Hazard Area Administrative Floodway.
>
> Development within an Alluvial Fan High Hazard Area, as determined using the Piedmont Assessment Manual shall be regulated in a manner similar to a floodway as described in Article Six, Sections 602 of these Regulations. Additional Development Standards for Zone A Alluvial Fan High Hazard Area Administrative Floodway are:
>
> Only major engineering measures as outlined in the Piedmont Manual may be used to mitigate the alluvial fan flood hazard in these areas.

Example.

Pima County, Arizona, has identified a 154-square-mile area as the Tortolita Watershed, consisting of the mountainous headwaters and sediment source and the associated alluvial fans. The following standards were recommended for application throughout the watershed (Cella Barr Associates, 1987):

- Washes with a 100-year peak flow in excess of 1,000 cfs should be maintained as natural undisturbed riverine environments, and detention facilities should not intercept them;
- The basin is designated as a “critical” basin, so development must decrease existing runoff;
- Drainage maintenance plans are required for developments that exceed 40 acres in the upper watershed or 120 acres in the lower watershed, or if they contain or abut a major wash or propose major channel modification;
- Rezoning densities should be maintained at or below those specified in a County-developed area plan (1.21 to about 2.70 residences per acre);
- Sedimentation should be considered in drainage studies; and
- Floodway surcharges and post-development velocities are limited.

Example.

Whatcom County, Washington, has mapped alluvial fans as one of several geologic hazards. The ordinance states, “No critical facilities shall be constructed or located in geologically hazard areas without fully mitigating the hazard.” Also, “All projects on an alluvial fan must be engineered and constructed to withstand alluvial fan hazards and/or flooding equivalent to the largest known event evident on the fan as determined by professional assessment” (Whatcom County, 1997).

Regulation of Areas Subject to Moveable Bed Streams

The management needs are somewhat different for the three types of moveable bed streams, so they are discussed separately.

Example.

In the State of Washington, the State Department of Ecology has developed the *Stormwater Management Manual for Western Washington* (Washington Department of Ecology, 2012) to maintain current levels of peak flow and sediment for all floods up to the 100-year event as a means of protecting its fisheries. This manual applies to all Washington communities west of the Cascade Mountains. Regulation of sediment transport throughout the watershed via this manual is allowing the watercourses to come into equilibrium, minimizing future erosion, sedimentation, and channel migration.

Areas Subject to Degradation—In stream reaches that are subject to channel degradation, the greatest potential threats are to development in the channel (including sand and gravel operations and public recreation facilities) and infrastructure in and adjacent to the channel (including flood control projects, roads, bridges, and buried utilities). If the channel degradation does not cause instability in the banks, protection of these facilities may be managed by construction standards and special use permits that recognize the hazards. If the banks are unstable, setbacks may also be needed. No regulations have been found that specifically address the increased future hazards associated with degrading streams.

Regulation of sand and gravel operations may be extremely important in some locations to control channel degradation but, to be effective, such regulation would have to be based on the kind of comprehensive modeling approach described by the State of Arizona. If a sand and gravel pit is located where floodwater can enter it, it may act as a sediment trap, allowing sediment to settle out. When the water leaves the pit, it is free of sediment, and immediately scours the bed downstream to restore its sediment load. Water entering the pit may also cause headcutting upstream from the pit. Detailed sediment transport studies are usually required to determine the effects of sand and gravel pits in floodplains, particularly in floodways.

Example.

Maricopa County, Arizona, has adopted a regulation specifically for sand and gravel operations. It states:

> A Floodplain Use Permit for the extraction of sand and gravel or other materials within the Floodway shall be granted if the

> applicant shows that excavations will not have cumulative adverse impact nor be of such depth, width, length, or location as to present a hazard to life or property or to the watercourse in which they are located and that they will comply with any applicable Watercourse Master Plan adopted by the Board of Directors. . . Excavations shall not be permitted so close to any floodway crossings, utility structures or facilities as to cause or have the potential to cause an adverse effect on such crossings, utilities or similar facilities... A plan of development shall be submitted with an application for a Floodplain Use Permit to the Floodplain Administrator. The Floodplain Administrator will determine whether an engineered plan will be required and whether a sediment transport analysis is necessary… The plan of development shall be required to include a plan of reclamation to leave the land when the approved use is terminated in such a condition as to maintain stability of the floodway by backfilling, contouring, leveling, removal of equipment and materials or other appropriate means… The plan of development is subject to post-flood review and possible modification if necessary due to flood related changes in river morphology.

Areas Subject to Aggradation—Aggrading stream reaches cause more flood damage in both the channel area and the overbank area than those expected if the reach is delineated using a fixed-bed model. In Maricopa County, Arizona, aggradation in the channel of the Gila River caused a 100-year flood to inundate the 500-year floodplain in 1980. The old primary river channel, choked with vegetation watered by sewage effluent, was filled with silt and a new channel was cut up to 1,500 feet away.

In western Washington, aggradation of the White River resulted in severe flooding of the City of Pacific in January 2009 when the Corps of Engineers released the same amount of water from Mud Mountain Dam, a short distance upstream of the City, as it had done three years earlier when very little flooding occurred.

Management of aggrading stream reaches should account for the ongoing loss of channel and/or floodplain conveyance capacity and the resulting increase in future flood elevations and larger areal extent of flooding in future events.

No existing local or state regulations have been found that specifically address the increased future hazards associated with aggrading streams. Setback lines and freeboard requirements provide some mitigation for these hazards, but if they are to provide true mitigation, they need to be based on a detailed study that forecasts future flood elevations and floodplain limits. Such studies may be included in mapping projects that are based on future-conditions hydrology.

Areas Subject to Channel Migration—In stream reaches where there is a history or geologic evidence of channel migration, floodplain management to reduce future flood damage must consider the possibility of future channel migration. The State of Washington has published guidelines on the determination of channel migration zones (Rapp and Abbe,

2003). Zones determined with these methods have been declared critical habitat for endangered salmon by the National Marine Fisheries Service (2008) and now receive additional protection. Mapping completed using this guidance is eligible for CRS credit.

Example.

King, County, Washington, has established setback lines along several rivers based on a study of historic and potential channel migration. Recent studies have been based upon the Framework published in 2003 by the Department of Ecology.

Example.

In 2008 the State of Vermont published the *Municipal Guide to Fluvial Erosion Hazard Mitigation* (Dolan, et al., 2008) which details risk assessment and mapping methods for risk due to unstable channels. Standards for construction within those areas also have been developed. These standards were used during the reconstruction of state highways after the floods of 2011.

Example.

Pima County and Tucson, Arizona, have established setback lines along all watercourses based on recent experience and an examination of selected floodplains. In Pima County, a developer must provide a detailed study, including a sediment transport analysis, in order to develop inside the setbacks. Setbacks range from 50 feet on minor washes to as much as 500 feet. The setback is from the channel bank or the 100-year floodplain, whichever is wider (Pima County, 2010).

Example.

In San Diego County, California, a Resource Protection Ordinance requires a setback of 100 feet or 15% of the floodway width, whichever is less, from the floodway boundary. Where erosion/sedimentation hazards are identified, no development is allowed. Also, the floodway is established using a maximum increase in flood elevation of 0.2 feet, and floodways are limited to velocities of 6 feet per second, which increases the floodway width in many steep floodplains. Although it is not quantifiable, these floodway restrictions should

provide more protection than floodways delineated using the standard FEMA criteria of an allowable 1.0 foot rise with no consideration of velocity.

Example 431UF-1.

In the Oriental Fan area, the mapping study upon which Arid County's regulations are based produced elevations based on water, sediment, and debris. Flood velocities are estimated throughout the area. New development must be designed to protect against these hazards. UFR1 = 80

In the West River floodplain, the County adopted a setback line and prohibits new buildings and fill within this area. This regulatory standard is credited under Activity 420UF.

Within 200 feet of Dry Creek, which is a degrading channel, the County requires all new buildings to have engineered foundations. UFR3(1) = 40

Public improvements and utilities within the floodplain are required to be designed to withstand the worst-case base flood and channel conditions. UFR3(2) = 40

UFR3 = UFR3(1) + UFR3(2) = 40 + 40 = 80

Impact Adjustment

The area affected by the special regulations must exclude areas designated as open space that are receiving Open Space (OS) credit under Activity 420 (Open Space Preservation).

As with other regulatory elements, areas for which open space credit (Activity 420) is requested must be excluded from the area credited for the special regulations.

$$rSHR = \frac{aSHR}{aSH}, \text{ where}$$

aSHR = the size of the area(s) that qualify for SHR credit, and

aSH = the size of the community's area of special flood-related hazard

If rSHR < 0.1, use 0.1

Credit Calculation

cSHDL2 = SHDL2 x rSHDL2

a. cIJR = IJR x rIJR

b. cCBR = CBR x rCBR

c. cMFR = MFR x rMFR

d. cSUR = SUR x rSUR

e. cUFR = (UFR1 x rUFR1) + (UFR2 x rUFR2) + (UFR3 x rUFR3) + (UFR4 x rUFR4), where r ≤ the value of r for Activity 420

f. cSHR =cSHDL2 + cIJR + cCBR + cMFR + cSUR + cUFR

The value of cSHR is used in Section 433 to determine the credit for Activity 430.

The maximum credit for cSHR is 150 points, so if cSHR is greater than 150 points, cSHR = 150.

Credit Documentation

(1) The community must provide the following documentation:

(a) The state or local law or ordinance that adopts the regulatory standard. See also Sections 231.b and c on documenting regulatory language.

(b) The Impact Adjustment Map.

(c) Permit records that document how the regulation has been applied.

The ISO/CRS Specialist will ask to see permit records for development in the special flood-related hazard area to verify that the regulations are enforced.

440 Flood Data Maintenance

Any special flood-related hazard areas should be included in the community's flood data. If the community has a GIS system used for floodplain management, all special flood-related hazards should be included in this system.

CRS credit (12 points) is provided for including special flood-related hazard areas in a geographic information system (GIS), in a digitized parcel system, or on an overlay map. This is found in Section 442, AMD7 of the *Coordinator's Manual.*

450 Stormwater Management

Although no specific credit is provided in this activity for special flood-related hazards, some items credited in the watershed master plan (WMP) may relate directly to these hazards. For example, in Activity 420, Example 421UF.1, Arid County receives open space credit because it prohibits development or fill in areas that are designated "active alluvial channels." Section 451.b of the 2002 *CRS Coordinator's Manual* provides WMP credit.

---

(5) 30, if the plan identifies existing wetlands or other natural open space areas to be preserved from development to provide natural attenuation, retention, or detention of runoff.

(6) 25, if the plan prohibits development, alteration, or modification of existing natural channels.

(7) 25, if the plan requires that channel improvement projects use natural or "soft" approaches rather than gabions, rip rap, concrete, or other "hard" techniques.

Arid County's regulatory requirements for the Oriental Fan area should qualify for all of these credit points because the regulations were adopted as a result of the hydrologic study performed by the Flood Control District for their watershed master plan.

500 Flood Damage Reduction Activities

Reducing the risk of damage from natural hazards has always been part of local planning and policymaking. By incorporating hazard information in a comprehensive plan, the local government can provide a sound basis and justification for those approaches that it decides to pursue in managing development and post-disaster reconstruction. Local governments have traditionally responded to natural hazards by delineating hazardous areas and by establishing land use controls, construction standards, and public investment policies governing development within those areas.

Planning tools are designed to guide land use and development patterns while assuring public safety and infrastructure services. Some states have established a planning framework for local governments that sets guidelines for local plans. Some encourage or require local governments to develop their own land use and development plans either for the entire community or for specifically defined resource management areas.

The causes of these special flood-related hazards, their locations, and the nature of the hazards make master planning an almost essential element of mitigation of the hazard. Consider that

- Ice jams tend to recur in the same locations;
- The hazards associated with closed basin lakes are due to their long duration of flooding;

- The locations of mudflow hazards can be mapped. If hazard maps are available for a community at a usable scale, they should be incorporated into the community's land use plan, hazard mitigation plan, etc.;
- Relatively large areas are affected by land subsidence, and the hazard develops over a long time period. Even in the case of sinkholes, which may appear suddenly, the causes of subsidence have been present for decades; and
- In areas subject to alluvial fan flooding, better floodplain maps may result from the use of watershed master planning, since seemingly minor obstructions or diversions at critical locations on alluvial fans may cause significant changes in the locations and quantities of downstream flows.

A combination of floodplain management and watershed management under a unified plan may be implemented to mitigate each of these special flood-related hazards.

510 Floodplain Management Planning

Communities are encouraged to prepare and adopt floodplain management plans that guide land use development, redevelopment, post-disaster recovery, and mitigation decisions. Credit for preparing, adopting, implementing, evaluating, and updating such a plan could be credited under Activity 510 (Floodplain Management Planning).

Section 511.a Step 4 (b)(1)c of the *Coordinator's Manual* provides extra points for a discussion of all special flood-related hazards that affect the community.

520 Acquisition and Relocation

As in riverine areas, acquisition and relocation of some structures may be the only viable way to reduce flood damage associated with these special flood-related hazards.

The technical feasibility of moving both small and large structures has been demonstrated on several occasions. Moving one- and two-story residential buildings has proven particularly cost-effective for readily movable structures.

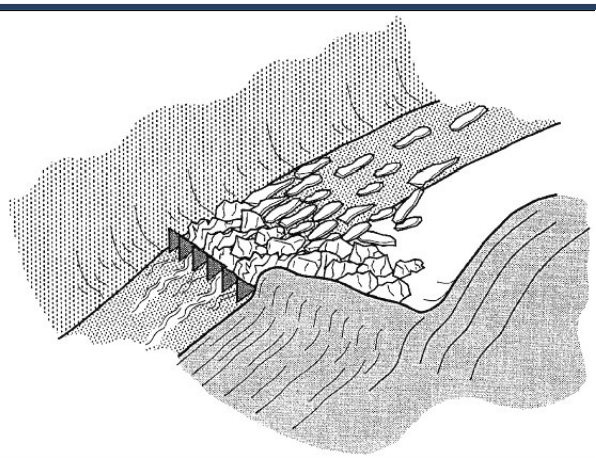
If there are structures in areas of uncertain flow path flooding that pose a danger to the occupants, or are repetitively flooded, acquisition and relocation may be the most cost-effective way of solving the problem. Credit for acquisition and relocation of properties in areas of special flooding areas is offered under Activity 520.

Except for repetitive loss structures and critical facilities in the 500-year floodplain, credit is only provided for buildings within the regulatory floodplain (aRF) that is managed by the community, so the mapping of special flood-related hazard areas in Activity 410SH may be important for this credit.

Acquisition and relocation of these properties may also significantly reduce the costs of maintaining and repairing infrastructure in these areas.

530 Flood Protection

There are various structural measures that may be effective in mitigating ice jam hazards. These measures differ according to the type of ice and the type of ice jam hazard expected. Due to the nature and/or the expense of structural measures that are effective in reducing ice jam hazards, it may be necessary to develop multi-jurisdictional or even multi-state projects. For more information, see the U.S. Army Corps of Engineers' *Ice Engineering Manual* (U.S. Army Corps of Engineers, 2002).



An ice control structure and ice storage area (from U.S. Army Corps of Engineers, 2002, p. 12-11).

In areas adjacent to closed basin lakes, structural measures should be considered a last-ditch effort to protect buildings and infrastructure from rising lake levels. Because lake levels tend to remain high for long periods of time, the water table will rise on the landward side of levees and flood walls. Structural measures may be effective if the lake level is approaching its outflow point. Structural measures (channelization) may be effective for lowering the maximum potential level of a lake, and this would be eligible for CRS credit for structural protection of buildings.

There are some structural measures that may be effective in mitigating mudflow and landslide hazards. These measures differ according to the type of hazard and its location relative to the community. Due to the nature and/or the expense of structural measures that are effective in mudflow or landslide hazards, it may be necessary to develop multi-jurisdictional or even multi-state projects.

If the rate of land subsidence is low, levees may provide protection, but they may be damaged as a result of differential land subsidence, making them subject to failure.

A variety of structural approaches to mitigate uncertain flow path hazards are in use to some extent in many communities. Sediment dams are expensive and require removal of the sediment by mechanical means after every major flood. Grade control structures and bank protection in reaches where channels tend to migrate are expensive and subject to failure. In general, the very nature of uncertain flow path flooding causes structural measures to be expensive and difficult to design.

A community that implements a project to reduce its risk from special flood-related hazards may be eligible to receive credit in Activity 530. A Letter of Map Revision should be submitted in those cases where a project would modify the SFHA. In other cases projects that meet the criteria of Activity 530 and reduce the existing risk may receive credit.

540 Drainage System Maintenance

Drainage system maintenance may be extremely important in areas with special flood-related hazards. The nature of some of these hazards indicates that there will be changes during every flooding episode and, in some cases, the hazard and the hazard area will change from time to time. It is important to inspect all channels and critical areas annually and after every significant event. These inspections help ensure that the system is not damaged and that debris is removed so that the system is fully operational. There is also credit in this activity for capital improvement plans that fund projects to reduce maintenance problems.

600 Warning and Response

Areas subject to special flood-related hazards are inherently more dangerous than most riverine floodplains because of the high velocities and the sediment and debris in the water. Although there is no specific credit in CRS Activities 610, 620, and 630, they deserve special attention by communities that face these hazards.

610 Flood Warning and Response

NOTE: *A separate publication,* ***CRS Credit for Flood Warning Programs****, includes examples of community programs and application documentation. Communities are encouraged to read this document before applying for flood warning credit. It will improve the quality of the application and reduce the need for additional documentation later. For a free copy, see Appendix C of the* ***Coordinator's Manual****.*

In communities with a history of ice jam flood damage, the community's emergency plan should include provisions to monitor stream conditions (threat recognition), warning dissemination, and evacuation planning for the area subject to ice jam damage. In most cases, ice jam flooding can be predicted, and advance warning can allow property owners to move building contents, vehicles, and animals away from areas that are to be flooded. If the area is only subject to higher flood levels as a result of an ice jam, some temporary floodproofing measures may also be effective where there is a warning.

Because closed basin lake flooding generally occurs over a long period of time (weeks, months, or years), flood warning is generally not needed as a mitigation tool.

Flood hazards due to land subsidence, on the other hand, may be mitigated by flood warning. Even though the hazard generally develops slowly, the increased flood hazard that results may include rapid-onset flooding.

In some communities, the U.S. Geological Survey and/or state agencies are actively working on systems to monitor potential mudflows in real time. Any community that would benefit from such a system should make sure that this system will serve as a warning mechanism by informing the public of the system, integrating the monitoring system into its

emergency response plan, and taking the other actions needed to use the real-time information effectively to save lives and reduce damage.

In many areas in the arid West, large tracts of land are owned by state and federal agencies and are virtually unpopulated. Flood warning may be needed for populated areas downstream. Due to the steep slopes in many of these areas, floods develop quickly in response to rainfall. They travel downstream rapidly and the flood levels rise quickly when the flows arrive. The watershed response time for a watershed of several thousand square miles may be less than 24 hours.

Traditional flood warning for these areas usually does not exist. There is little population in the watershed, so there are few rain gages. The streams are usually dry, so there are few stream gages.

A number of large communities, counties, and even states have developed ALERT (Automated Local Evaluation in Real Time) warning systems in the watersheds that affect them. See Activity 610 in the *Coordinator's Manual* for a discussion of these flood warning systems.

620 Levees

Levees in areas of channel migration or where there are ice hazards may require more frequent and more extensive maintenance due to erosion, sedimentation, and channel migration. Levees may also require special construction standards and/or maintenance if they are in areas subject to subsidence, or if they are in long-term contact with water adjacent to a closed basin lake.

630 Dams

Dams in areas of special flood-related hazards are no more or less unsafe than other dams. However, they serve as sediment traps, and their effective lifetime is limited unless the sediment is removed. In some areas, dams have been built for the specific purpose of removing sediment from streams upstream from developed areas so that the channels below remain more stable. The reservoir areas behind these dams must be cleaned frequently or they will become ineffective.

REFERENCES

Cella Barr Associates. 1987. *Tortolita Fan Area Basin Management Plan,* Phase I and Phase IA. Prepared for the Pima County Flood Control District. Tucson, AZ.

Dolan, K., M. Kline, and B. Cahoon. 2008. *Municipal Guide to Fluvial Erosion Hazard Mitigation*. Waterbury, VT: Vermont Agency of Natural Resources. http://www.vtwaterquality.org/rivers/docs/rv_municipalguide.pdf.

FEMA. 1989. *Alluvial Fans: Hazards and Management*. FEMA 165. Washington, D.C.: FEMA. http://www.fema.gov/library/viewRecord.do?id=1633.

FEMA. 2003. *Guidelines and Specifications for Flood Hazard Partners, Appendix G: Guidance for Alluvial Fan Flooding Analyses*. Washington, D.C.: FEMA. http://www.fema.gov/library/viewRecord.do?id=2206.

FEMA. 2002. *Flood Insurance Study Guidelines and Specifications for Study Contractors, Appendix F*. Washington, D.C.: FEMA. http://www.fema.gov/library/viewRecord.do?id=2206.

FEMA Region 10. 2012. *Floodplain Management and the Endangered Species Act, A Model Ordinance*. http://www.fema.gov/national-flood-insurance-program-endangered-species-act.

Gabrysch, R.K.. 1983. "The Impact of Land-surface Subsidence." Pp. 117–123 in *Impact of Science on Society, Managing our Fresh-water Resources*. Paris: United Nations Educational, Scientific and Cultural Organization.

Galloway, Devin, David R. Jones, and S.E. Ingebritsen, eds.. 1999. *Land Subsidence in the United States.* Circular 1182. Reston, VA: U.S. Geological Survey.

Holzschuh, J.C.. 1991 *Land Subsidence in Houston, Texas, USA*. Field-trip guidebook in conjunction with Fourth International Symposium on Land Subsidence, Houston.

Leake S.A.. 1997. "Land Subsidence from Ground-Water Pumping." Paper presented at the Workshop of the U.S. Global Change Research Program Workshop. University of Arizona, September 1997. Reston: U.S. Geological Survey. http://pubs.er.usgs.gov/publication/fs12197.

Miller, Marli Bryant. 2005. "Geological Landscapes of the Death Valley Region." *Earth-Science Reviews* 73: 17–30. http://darkwing.uoregon.edu/~millerm/DVscapes.pdf.

National Marine Fisheries Service. 2008. "Endangered Species Act – Section 7 Consultation Final Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation." NMFS Tracking No. 2006-00472. http://www.fema.gov/media-library/assets/documents/30021?id=6752.

National Research Council. 1996. *Alluvial Fan Flooding*, Washington, D.C.: National Academy Press. http://lab.nap.edu/napsearch.php?term=alluvial fan flooding&restric=NAP.

Newton, J.G.. 1984. "Case History No. 9.11. Alabama, U.S.A." Pp. 245-251 in Joseph F. Poland, ed., *Guidebook to Studies of Land Subsidence due to Ground-water Withdrawal*. Prepared for the International Hydrological Programme, United Nations Environmental, Scientific, and Cultural Organization. Studies and Reports in Hydrology 40. Paris: UNESCO. http://wwwrcamnl.wr.usgs.gov/rgws/Unesco/.

Pima County, Arizona. 2010. Title 16 of the Pima County Code. http://library.municode.com/index.aspx?clientId=16119.

Rapp, C.F. and T.B. Abbe. 2003. "A Framework for Delineating Channel Migration Zones." Ecology Final Draft Publication #03-06-027. http://www.ecy.wa.gov/biblio/0306027.html.

U.S. Army Corps of Engineers. 2002. *Ice Engineering*. Manual No. 1110-2-1612 Washington, D.C.: Corps of Engineers. http://publications.usace.army.mil/publications/eng-manuals/EM_1110-2-1612_pflsec/toc.htm.

U.S. Army Corps of Engineers. 2006. "What is the Ice Jam Database?" http://icejams.crrel.usace.army.mil/.

U.S. Geological Survey. 2007. http://ut.water.usgs.gov/greatsaltlake/elevations/gslelevgraphs/GSL.WSAlt.Aug07.pdf.

Washington Department of Ecology. 2012. *Stormwater Management Manual for Western Washington*. http://www.ecy.wa.gov/programs/wq/stormwater/manual.html.

Whatcom County. 1997. *Whatcom County Critical Areas Ordinance*. Bellingham, WA: Whatcom County.

Appendix A

ACRONYMS

AMD—additional map data

CAZ—coastal A zone regulations

CBR—closed basin lake hazard regulations

CMZ—channel migration zone

DL—development limitations

FIRM—Flood Insurance Rate Map

GIS—geographic information system

IJR—ice jam regulations

LZSH—special hazard low density zoning

MAPSH—mapping special hazards

MCB—mapping closed basin lakes

MFR—mudflow hazard regulations

MIJ—mapping ice jams

MMF—mapping mudflow hazards

MSU—mapping land subsidence

MUF—mapping uncertain flow path hazards

OS—open space

OS—preservation of open space

PPI—Program for Public Information

RF—regulatory floodplain

SFHA—Special Flood Hazard Area

SH—size of the community's area of special flood-related hazards

SHOS—special hazards open space

SUR—land subsidence regulations

UFOS—uncertain flow path open space

UFR—uncertain flow path regulations

UFR1—alluvial fan regulations

UFR2—aggrading stream regulations

UFR3—degrading stream regulations

UFR4—channel migration regulations

WMP—watershed master plan