APPENDIX A - REACH SUMMARIES

General

This appendix contains summaries of all field data and office analyses for each reach and subreach studied on the East Fork, West Fork, Brockliss Slough and Carson River. The intent of the reach summaries is to provide a condensed version of all data collected and analyses conducted to be used as a tool for further planning and as a baseline study for further investigations. For each reach studied, this appendix includes:

- Reach Map A map showing the river, adjacent towns or other prominent geographic features, locations of cross-sections (when available), major roads and reach boundaries, and a graphic stability rating.
- Geomorphic Setting A description of the primary geomorphic processes and controls, including anthropogenic controls, that are occurring in the reach.
- Channel Capacity A summary of channel capacity and channel cross-section information as determined through hydraulic analyses of each cross-section.
- Field Form Summary A summary of all information recorded on field study forms which includes stability ratings, primary land use, bank condition and stability, and vegetative condition.
- Recommendations Channel recovery and land management recommendations which are specific to the reach and related to geomorphic processes affecting the reach.

The following reach summaries incorporate all data and analysis from Inter-Fluve, Inc. field investigations, agency personnel, land owner and historic perspectives, air photo interpretation, cross-sections and at-a-station hydraulic analyses, and other available studies and investigations. The reach summaries are based on qualitative and quantitative analyses conducted by Inter-Fluve and represent Inter-Fluve's perspectives which are based on our experience with similar problems and issues, our expertise in the field of geomorphology and river restoration, and on our professional judgment. Other information, on which the Reach Summaries are based, is documented in subsequent appendices.

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E-1 REACH SUMMARY

SUB-REACHES: N A
LOCATION:Nevada State Line to Washoe Rd. Crossing

Geomorphic Setting

Rosgen/Downs/Harvey-Watson Classifications
B4c/S/NA

General

Because E-1 was considered a low-priority reach, little field observation was conducted. Field observation was limited to a field form completed by Dan Kaffer (NRCS) at Horseshoe Bend, and to field team observation of Broken Dam and a short distance immediately upstream. E-1 is a relatively steep (2% estimated), bedrock, boulder and cobble bed stream. The upper portion is largely unconfined, while the lower section flows through a narrow bedrock canyon. In addition to Broken Dam, bedrock offers vertical grade control throughout the reach, while lateral stability is provided by riparian vegetation and topography in the upper section, and bedrock in the lower section.

Broken Dam, at the bottom of the reach, has backwatered the East Fork several thousand feet up the canyon, and has a considerable drop below the dam. While this acts as a grade control, the deteriorated status of the dam may be considered a significant hazard in the event of failure. Furthermore, the tremendous volume of sediment accumulated upstream of the dam may jeopardize downstream stability in the event of dam failure as it will send a considerable surge of sediment downstream possibly for a number of years.

Channel Capacity

No surveying or hydraulic analysis was conducted in this reach. However, casual observation indicates that the channel capacity is consistent with a relatively natural and healthy system.

Land Use

Land use is primarily grazing and recreation.

Relative Stability
stable

General

E-1 is considered stable, largely due to minimal human manipulation of the channel or banks and the bedrock controls. As stated above, the condition of Broken Dam may lead to channel instability for some distance upstream and downstream of the dam in the event of dam failure.

Bank Stability
moderate

Bank stability is moderate, largely due to riparian vegetation condition. Bank erosion occurs mostly at outside bends.

Vegetative Condition

No observations of vegetative condition or riparian zones were recorded. Limited comments on vegetative condition indicate that riparian vegetation is limited and in poor to fair condition.

Channel Recovery And Land Management Recommendations

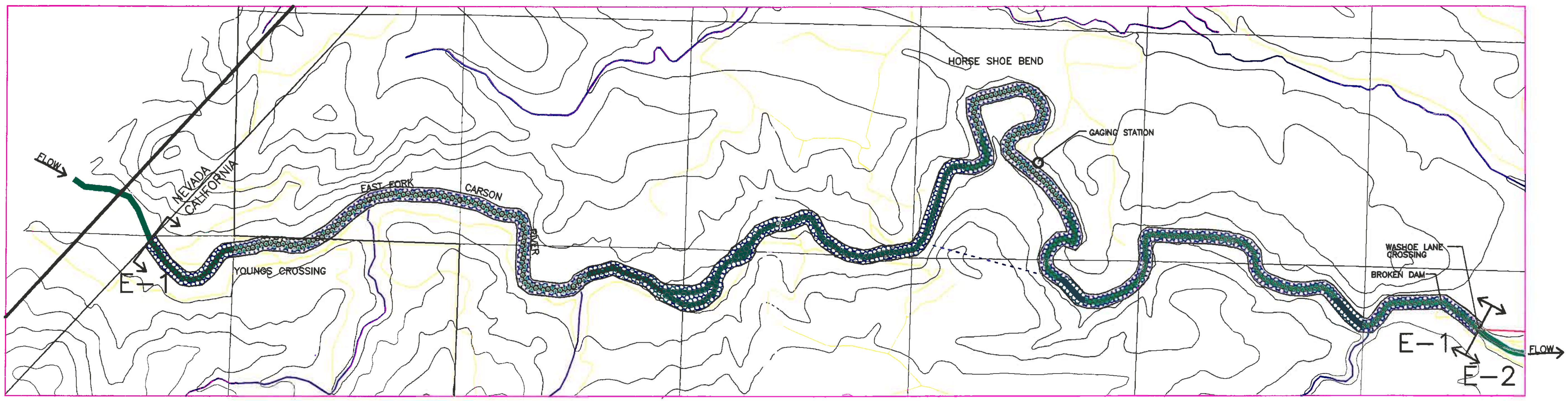
NOTE TO READERS:

This report was originally submitted in December of 1996, prior to the New Year's Flood of January 1997. It should be noted in reading this document that the conclusions and recommendations stated in this report are based on observations which were made previous to the geomorphically significant flood event. The physical state of much of the observed areas has been significantly altered. In many reaches and subreaches, physical change resulting from these floods has been so significant as to render some recommendations inappropriate. Where such changes have been observed by local land managers, their opinions as to the appropriateness of recommendations should be observed. However, in our opinion, while site specific and short term recommendations may be less appropriate following the flood, general and long-term management considerations are still appropriate and relevant on a watershed scale.

- Manage reach for continued riparian fringe vegetation and recreation. This may include planned grazing activities such that the existing vegetation is not degraded. Overall reach stability does not suggest the need for any channel or bank stabilization activities. The need for any proposed mechanical activities should be carefully considered.
- Consideration should be given to removal of Broken Dam. Existing conditions indicate that the dam may be unstable, and could potentially cause channel instability and hazards in the event of failure. We recommend that a feasibility study be conducted in the near future to determine the strategy and costs for removal of the dam. Such a feasibility study should include:
    1. Determine extent of deposition upriver in canyon that resulted from dam backwatering.
    2. Use seismic studies to determine depth to bedrock, generate cross-sections of subsurface materials.
    3. Estimate gravel to be excavated from profile study and seismic study.

  It is possible that costs for removal of the dam may be offset by sale of the gravels excavated from backwatered areas.

  The construction sequence for dam removal will likely involve the following steps:
    1. Establish a dewatering system from the top of the excavation area, route water to below dam.
    2. Remove dam.
    3. Excavate and haul material from the bottom up, using the dewatered river bed as a haul road.
    4. Create a stream environment using bedrock as a base level, and using the haul road materials to create bars as appropriate.
    5. Build stream from top to bottom, remove haul road from top to bottom.



REACH E-1

APPOX. SCALE: 1" = 2500'

NORTH

LEGEND

- CARSON RIVER
- ROADS
- MAIN ROADS
- TRIBUTARY CHANNELS/DITCHES
- CROSS SECTION

STABILITY

- EXTREMELY UNSTABLE
- UNSTABLE
- MODERATELY UNSTABLE
- STABLE
- VERY STABLE

E-2 REACH SUMMARY

SUB-REACHES: S1, S2, S3, S4
LOCATION: Washoe Rd. Crossing to Country Club Bridge

Geomorphic Setting

Rosgen/Downs/Harvey-Watson Classifications

S1: B2c/S/IV S2: B3c/S/NA S3: B3c/M/NA S4: B3c/C-R/NA

General

Reach E-2 is the first East Fork channel section which is unconfined by canyon side slopes; some natural terrace confinement is present on the left bank of S1. Comparison of 1938 and 1990 aerial photo tracings of active channel width and thalweg indicates straightening of the S1 channel. Levee construction by the BOR in 1965 reduced channel length by up 15 percent in S1 and S3, and increased active channel width by up to five times in some areas. What was once a very sinuous, irregular shaped and depositional channel environment was converted into a straight, trapezoidal channel which very efficiently transports small cobble and smaller substrate sizes. The result of straightening also increased channel energy in S1 such that the channel bed experienced degradation. Estimates of historic bed degradation are difficult due to extensive overbank grading and filling of historic floodplain surfaces. Three feet is a general estimate of incision for S1 between 1938 and 1990.

Due to the proximity of the canyon upstream (Reach E-1), channel substrate sizes fall into the large cobble category in E-2. The cobble appears to have effectively armored the channel bed, preventing further incision. In fact, moving downstream through S2, S3 and S4, channel base levels today do not appear greatly incised; currently there is evidence of channel aggradation within straightened sections. It is unclear whether observed aggradation is a recent phenomenon. It is possible that S2, S3, and S4 experienced incision following straightening (less severe than in S1 but still significant) and are now aggrading. Bed substrate is largely unsorted in all sub-reaches. Channel shape can be generally described as trapezoidal to parabolic to irregular, in the downstream direction.

Channel Capacity

S1: Levees and channel incision in this reach have resulted in a channel which contains the estimated 100-year flow. Floodplain elevations, on the right bank, appear to be equivalent in elevation to the stage of the discharge between the 10- and 25-year flow. Bar forms in the channel roughly correspond with annual maximum flows.

S2: As in S1, levees and incision have created a channel which conveys between the 50- and 100-year discharges. Some bar forms in this section have a maximum elevation at the stage of the estimated 2-year flow.

S3: The levee on the right bank likely contains flows up to or above the 25-year stage. The left bank consists of a significant bar form, the highest point of which corresponds to the stage of a 2-year discharge.

S4: This cross-section was located in an aggradational area above a diversion which has numerous channels and mid-channel bars. All bar heights occur at elevations less than those of the stage of a 1.25-year event and are therefore likely the result of annual high flows, indicating a dynamic cross-section with highly mobile bar forms. The left bank levee, adjacent to the golf course, contains all flows up to and well above the 100-year discharge. The right bank floodplain is at an elevation which corresponds to the 25-year discharge.

Land Use

Land use varies from recreational in the upper sub-reaches to ruralized, grazing, golf course, trailer parks, fences, and roads in lower sub-reaches.

Relative Stability

Stable to Moderately Unstable

General

Due to its proximity to the upstream canyon sections, bed substrate is dominated by cobble up to 12" in the upper subsections. The generally large cobble sizes have promoted an armored bed resistant to bed degradation. Sub-reaches S1 and S2 were classified as stable; bar forms are alternate. Reaches S3 and S4 are moderately unstable; bar forms are point/alternate and point/mid-channel, respectively. The latter instability is related to lateral channel migration in areas where bank riparian vegetation is sparse. Mid-channel bars in S4 are indicative of a depositional environment which may be promoting instability here as the channel responds by gaining additional channel width.

Bank Stability

S1: stable S2: stable S3: moderate S4: moderate

The majority of all banks in this reach are 2:1 or flatter. Banks heights range from 2 to 10 feet, with the majority between 4 to 6 feet. Bank heights generally increase in the downstream direction, which matches the increase in instability. Reaches S1 and S2 bank failures are confined to very short distances due to levee toe undercutting; vegetation on the channel fringe is well established. In contrast S3 and S4 instability is associated with outside bend erosion (undercutting and basal cleanout) and/or at areas of localized aggradation; 10% of these banks are vertical and associated with an absence of vegetation. Bank alterations observed include: levees (S1 and S2), levees and grazing (S3), and active bank resloping (S4, 5% of sub-reach). Bank materials range from largely uncohesive cobble/gravel (S1 to S3) to uncohesive small gravel/sand/silt in S4. Note that downstream fining of bank substrate is coincident with evidence of bank erosion.

Vegetative Condition

Outside Levees: The historic floodplain areas in E-2 are in variable land use and condition. Scattered mature cottonwoods are found in S1 and S2. By S3 and S4, the vegetative state is a mixed group of irrigated pasture, sparse sage and rangeland.

Inside Levees: Channel fringe vegetation is generally abundant in all sub-reaches, though density falls off somewhat in S3 and S4. Vegetative type is generally described as commonly occurring sprout and young willows, with some young cottonwoods and mature willows. Cottonwoods on the levees are generally the age of the levees (30 years). Bars are typically well vegetated with willows and some young cottonwoods. Diversity is considered moderate throughout, due to the absence of mature/decadent overstory cottonwoods.

Channel Recovery And Land Management Recommendations

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While not necessarily a channel recovery strategy, protection of infrastructure at risk is generally recognized as a first priority in unstable systems. These fall into two categories: 1) those related to threat via channel migration and, 2) threat of flooding. In terms of flooding, these risks are more difficult to identify due to the relative infrequency of the 100-year magnitude flood. In light of the above, the following general recommendations are made:

- Conduct a risk assessment to identify private and public infrastructure at risk.
- Develop river stabilization or stress alleviating schemes for areas where significant private or public infrastructure is threatened by river migration.
- Re-assess the current zoning regulations regarding future development in flood prone areas. Insure this assessment relates to an accurate and current 100-year floodplain delineation.

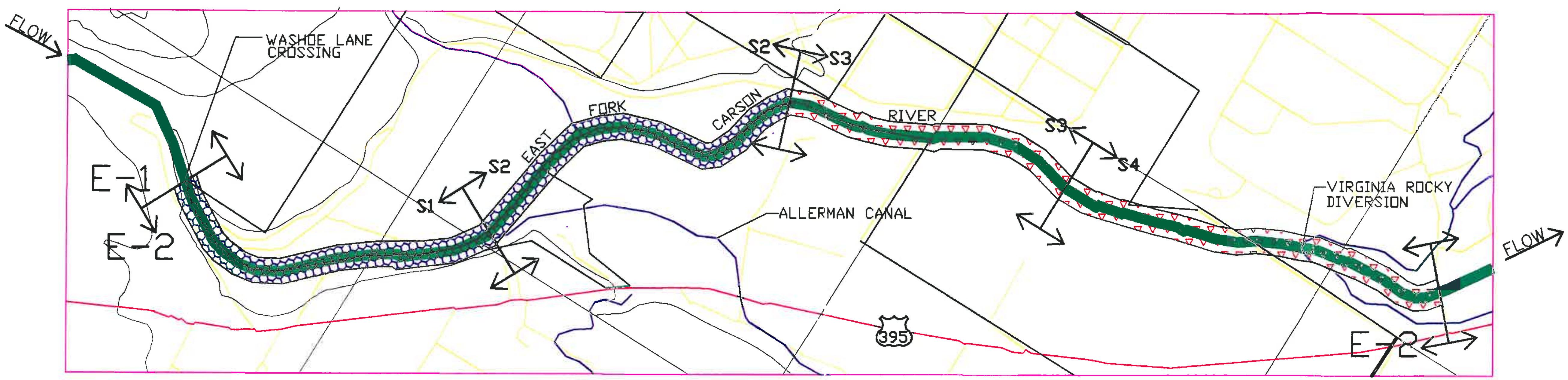
Regarding infrastructure protection, bear in mind that engineered solutions should focus only on at-risk infrastructure at first. Also, as with all river projects, the impacts of the stabilization or floodplain management/development schemes on the hydrologic and geomorphic behavior of the river should be fully analyzed prior to implementation. *All* stabilization schemes should follow the following best practices:

- A complete assessment of the possible effects on upstream and downstream river stability from project implementation.
- Professionally designed and engineered treatments with clearly identified factors of safety and design criteria.
- The use of treatments which will also provide benefits for fish and wildlife.
- Identification of likely failure scenarios and the anticipated costs for long-term maintenance.
- Professionally installed treatments.

To stabilize this reach of the Carson River system, one would need to: 1) consider both lateral and vertical control measures, 2) the influence of a large in-channel sediment supply and the efficient transport of that supply downstream and, 3) the effects of large floods, which the Sierra drainages are very capable of producing. All engineered approaches should adhere to the Basic Design and Engineering Standard Practices for Channel Work described on page 30 or the main text.

- Diversion Structures: We recommend that loose rock diversion structures be replaced with more permanent diversion structures or pumping galleries, in conjunction with the consolidation of diversion points to eliminate unnecessary structures. Conceptually, if the existing permanent structures could be re-engineered to allow for greater bedload transport during moderate and frequent high flow events, overall sediment transport continuity on the river may be improved. Replacement with pumping systems would allow for natural river function without the negative effects of diversion structures. The benefits of improved sediment transport may be difficult to quantify, though allowing the river the "freedom" to move bedload downstream in as natural a manner as possible is consistent with aided natural recovery options
- General: The central strategy for these reaches should be to reduce the delivery sediment to the Carson River. Given the East Fork's tendency to gain width, recovery activities would likely involve increasing channel width and the construction of a floodplain which is inundated on a bi-annual basis. These efforts would involve a great deal of earth moving and stabilization of the new channel fringes, among other activities.
- S1: Manage reach for continued riparian fringe vegetation and recreation. This may include planned grazing activities such that the existing vegetation is not degraded. Overall reach stability does not suggest the need for any channel or bank stabilization activities. Any proposed mechanical activities should be carefully scrutinized as to need.
- S2: Manage reach for continued riparian fringe vegetation and recreation. Maintain riparian fencing and consider any grazing activities within the context of the existing recreational uses and riparian vigor. Overall reach stability does not suggest the need for any channel or bank stabilization activities. Any proposed mechanical activities should be carefully scrutinized as to need.
- S3: Some bank instability problems may be addressed in this area through better riparian management (controlled or excluded grazing) and some mechanical means. Problem areas are associated with lack of vegetation. Continue riparian planting in this area. Outside bends/area of undercutting could benefit from the installation of a rock toe in conjunction with some bank slope pull-back (to 3:1 or less) and revegetation.
- S4: See S3 recommendations. Additionally, some bank erosion in this area is associated with aggradation behind the Virginia Rocky diversion. In the current state, continued bank erosion is expected above the diversion. It may be possible to address bank erosion problems with mechanical means, though the diversion will continue to put pressure on upstream banks. Reconfiguration of the diversion can be considered to eliminate aggradation, though the costs of such an effort may exceed that needed to stabilize upstream banks. As with all reaches, any designed

channel work should demonstrate no downstream impacts with appropriate analysis.



REACH E-2

APPOX. SCALE: 1" = 1500'

NORTH

LEGEND

- CARSON RIVER
- ROADS
- MAIN ROADS
- TRIBUTARY CHANNELS/DITCHES
- CROSS SECTION

STABILITY

- EXTREMELY UNSTABLE
- UNSTABLE
- MODERATELY UNSTABLE
- STABLE
- VERY STABLE

E-3 REACH SUMMARY

SUB-REACHES: S1, S2
LOCATION: Riverview Road Bridge to Centerville Road Bridge

Geomorphic Setting

Rosgen/Downs/Harvey-Watson Classifications

S1: F3/D-d/NA S2: F4/m/II-III

General

Reach E-3 has been extensively disrupted by channelization, levee confinement, and diversion structures. There is one predominant diversion structure, the Cottonwood Diversion, which has had significant impacts on the channel system up- and downstream of the structure. 1938 aerial photos indicate that the channel was once a sinuous, multi-thread channel. Levee construction and channelization have created a trapezoidal channel above the diversion, to a rectangular channel below the diversion. Bedload transport is affected by both the levee confinement and by the Cottonwood Diversion. Upstream of the diversion is an aggraded reach with restricted transport, while downstream is an entrenched system characteristic of channelized systems with a bedload supply limited by the diversion structure. This is further demonstrated by an increase in bed particle size, from sand and gravels above the diversion, to largely cobble and gravel immediately below the diversion.

Reach S1 exhibits primarily alternate bars indicating a trend toward greater sinuosity within the confined system. S2 exhibits primarily point and mid-channel bars.

Channel Capacity

Hydraulic analysis was not possible for cross-sections in E3 due to insufficient data. However, cross-sectional areas and the presence of levees indicate that conveyance is similar to that in E-2 where large magnitude events are contained within the channel and levees.

Land Use

Land use is predominantly agricultural and grazing lands with nearly continuous levees and fences.

Relative Stability

Moderately Unstable

General

Evidence of past channel instability includes a deeply entrenched system below the diversion structure. While the channel appears to be approaching a stable grade following incision, lateral stability is still an issue due to confinement. The low flow channel is actively migrating within the entrenched system below the diversion and within the aggraded reach above the diversion, eroding banks as it migrates. These erosional forces are exacerbated by the entrenched and confined system which prevents overbank flow. Largely unvegetated bars may be indicative of either rapid low flow channel migration rates or water supply problems due to withdrawals.

Bank Stability

S1: Moderate S2: Moderate

The percentage of banks which are considered unstable is 5 percent in S1 and 25 percent in S2. This increase in bank instability appears to be associated with the higher degree of channel entrenchment below the diversion. Bank heights range from 4-14 feet above the diversion and from 10-30 feet below the diversion. Bank failures in both sections are largely at outside bends and constrictions, indicating a trend towards channel lengthening due to either aggrading conditions above the diversion or channelization and entrenchment below the diversion. Most banks are steep levee slopes and are failing due to undercutting and basal cleanout. Undercutting is occurring upstream of the diversion, while basal cleanout (associated with reduced bedload supply) is dominant below the diversion. The majority of channel banks are well vegetated and relatively stable. Bank materials are largely unconsolidated levee materials consisting of cobbles and gravels. Bank alterations include continuous levees with isolated riprapped sections.

Vegetative Condition

Outside Levees: The floodplain areas in E-3 are largely non-functional due to levees restricting floodplain access and, in sub-reach S2, as a result of channel incision which has lowered the channel bed relative to the floodplain. In S1, there is fairly dense cover of grasses, shrubs and scattered trees. In S2, floodplain areas outside the levee are largely rangeland with sparse shrubs.

Inside Levees: The riparian corridor is essentially contained within the levees and ranges from 0-50 feet in width. In S1, riparian vegetation is abundant with moderate structural diversity, and with all age classes well represented. However, there is a noticeable lack of dead or decadent riparian vegetation, indicating that it has not matured and that the riparian corridor is likely younger that the levees which contain it. The riparian corridor in S2 is similar to that in S1, though much of the riparian corridor is on steep levee banks and significantly higher than the channel elevation, due to channel incision.

Channel Recovery And Land Management Recommendations

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While not necessarily a channel recovery strategy, protection of infrastructure at risk is generally recognized as a first priority in unstable systems. These fall into two categories: 1) those related to threat via channel migration and, 2) threat of flooding. In terms of flooding, these risks are more difficult to identify due to the relative infrequency of the 100-year magnitude flood. In light of the above, the following general recommendations are made:

- Conduct a risk assessment to identify private and public infrastructure at risk.
- Develop river stabilization or stress alleviating schemes for areas where significant private or public infrastructure is threatened by river migration.
- Re-assess the current zoning regulations regarding future development in flood prone areas. Insure this assessment relates to an accurate and current 100-year floodplain delineation.

Regarding infrastructure protection, bear in mind that engineered solutions should focus only on at-risk infrastructure at first. Also, as with all river projects, the impacts of the stabilization or floodplain management/development schemes on the hydrologic and geomorphic behavior of the river should be fully analyzed prior to implementation. *All* stabilization schemes should follow the following best practices:

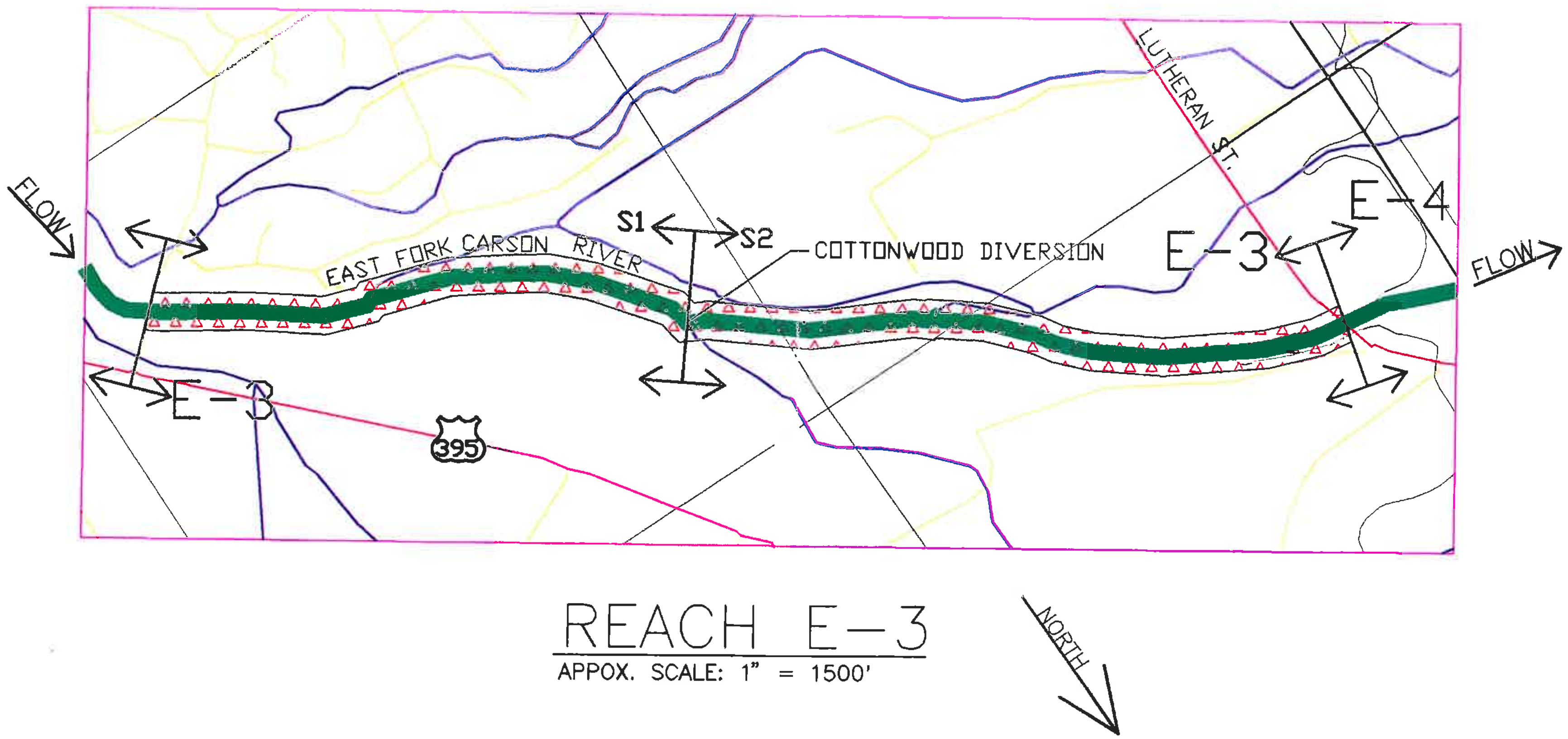
- A complete assessment of the possible effects on upstream and downstream river stability from project implementation.
- Professionally designed and engineered treatments with clearly identified factors of safety and design criteria.
- The use of treatments which will also provide benefits for fish and wildlife.
- Identification of likely failure scenarios and the anticipated costs for long-term maintenance.
- Professionally installed treatments.

To stabilize this reach of the Carson River system, one would need to: 1) consider both lateral and vertical control measures, 2) the influence of a large in-channel sediment supply and the efficient transport of that supply downstream and, 3) the effects of large floods, which the Sierra drainages are very capable of producing. All engineered approaches should adhere to the Basic Design and Engineering Standard Practices for Channel Work described on page 30 or the main text.

- Lutheran Bridge: Potential failure of the downstream Burnell irrigation diversion dam could promote local bed incision which may result in pier scour, though the bridge currently appears in good shape.
- Diversion Structures: We recommend that loose rock diversion structures be replaced with more permanent diversion structures or pumping galleries, in conjunction with the consolidation of diversion points to eliminate unnecessary structures. Conceptually, if the existing permanent structures could be re-engineered to allow for greater bedload transport during moderate and frequent high flow events, overall sediment transport continuity on the river may be improved. Replacement with pumping systems would allow for natural river function without the negative effects of diversion structures. The benefits of improved sediment transport may be difficult to quantify, though allowing the river the "freedom" to move bedload downstream in as natural a manner as possible is consistent with aided natural recovery options
- General: The central strategy for these reaches should be to reduce the delivery sediment to the Carson River. Given the East Fork's tendency to gain width, recovery activities would likely involve increasing channel width and the construction of a floodplain which is inundated on a bi-

annual basis. These efforts would involve a great deal of earth moving and stabilization of the new channel fringes, among other activities.

- S1: Manage reach for increased riparian corridor width. While expensive and vast in scope, reconstruction of levees further away from the stream channel would allow for a wider meander and riparian corridor, while still offering levee protection. However, due to the limited development along this reach, there appears little justification for such actions. The Cottonwood Diversion appears to be a large factor in channel stability. Redesign of the structure to allow bedload transport during high flows would likely improve channel stability.
- S2: The same management recommendations apply to S2 as for S1. The entrenchment of the channel in S2 decreases potential for overbank flows, relative to S1, and therefore lessens the need for levees. S2 would benefit from increased bedload transport through the diversion from S1.



REACH E-3

APPOX. SCALE: 1" = 1500'

LEGEND

- CARSON RIVER
- ROADS
- MAIN ROADS
- TRIBUTARY CHANNELS/DITCHES
- CROSS SECTION

STABILITY

- EXTREMELY UNSTABLE
- UNSTABLE
- MODERATELY UNSTABLE
- STABLE
- VERY STABLE

E-4 REACH SUMMARY

SUB-REACHES: S1, S2
LOCATION: Lutheran Bridge to Highway 88 Bridge

Geomorphic Setting

Rosgen/Downs/Harvey-Watson Classifications

S1: B3c/E,m/III-IV S2: F4/E,M,U/III

General

This reach is through a wide valley bottom with no natural topographic constraints. However, the channel is confined on both banks by push-up gravel levees (mostly dating to 1965 BOR work), many with rip rap toes, which suggests some maintenance following original work. While 1938 to 1990 aerial photo comparisons are incomplete for this reach, information at hand reveals: the 1938 channel had multiple threads, active channel widths up to 600 feet and moderate sinuosity. Anecdotal accounts also suggest that the river was coupled with its floodplain, resulting in frequent out of bank flows. However, at all cross-sections surveyed, the channel now conveys the 100-year or greater discharges. The 1990 photos suggest that the main effort of the 1964 levee work was to convert the channel to a single thread by greatly narrowing the active channel width. Ground evidence also suggests that the levees were designed to contain flood flows. There is some evidence of historic (post-levee) channel incision as well as aggradation. Incision seems dominant in S1, while S2 has a history of both. Much of S2 appears to be relatively coupled with its floodplain, while S1 is entrenched. Ongoing work on the channel, including diversion construction and gravel removal, has been in response to channel changes. These efforts have obscured many natural geomorphic trends. Channel bed D_{50} was estimated to range form 3" (S1) to (S2) 1.5"; D_{max} 10" to 8", respectively. Substrate is relatively unsorted, suggesting continuously changing bedload supply and/or flood magnitudes.

Channel Capacity

S1: Two cross-sections were surveyed in S1. Both show that flows greater than the 100-year discharge are contained within the channel. Both sections show bar form development at annual maximum high flow stages and at the stage of the 2-year discharge.

S2: As in S1, the channel conveys the 100-year flow. Furthermore, it appears that the floodplain elevation is roughly equivalent to the stage of the 50-year flow, indicating extreme incision and excess channel cross-sectional area.

Land Use

Infrastructure, (houses, light industry, out-buildings) grazing, and agricultural uses dominate the area adjacent to the channel.

Relative Stability

Moderately Unstable to Unstable

General

In a downstream direction, channel stability ranges from moderately unstable to unstable. Judging from the historic floodplain elevation, incision from historic base level may extend from 6 to 10 feet. In S1, some channel enlargement via incipient meander development is evident. The bed is active, as indicated by alternate and large transverse bars. Incipient pool/riffle sections are evident, but may be transitory due to irregular bedload movement in association with changing local base levels. Grade through S1 is intermittently controlled by abandoned and active channel diversions, whose effect on channel grade is significant. However, these structures are non-permanent. For example, the Burnell diversion has been moved upstream a number of times in recent history (post-levee) as the channel bed has incised at the original diversion point. It is currently just below the Lutheran Bridge, and has a drop of 3.6 feet over 10 feet; there is not an opportunity to move the diversion further upstream to obtain more drop. Aggradational features upstream of abandoned diversions points may not remain should the remaining structure completely fail.

S2 is unstable in both vertical and lateral dimensions. Conversations with Fred Stodieck, a landowner, indicate a recent history of both channel change and ongoing manipulation of the channel. During the 1950's this reach of river regularly accessed its floodplain, accepted by the landowners as normal behavior. Therefore, the BOR was not allowed to build through the Stodieck property. Soon after levee construction, the channel rapidly aggraded, likely due to proximity to the confined and efficient transport reaches upstream. This material was removed over time as it aggraded to improve channel capacity so that the agricultural ground and nearby houses were less susceptible to flooding. Material removed has been placed in levees. However, the levees are not sufficient to impede lateral migration, as evidenced by several lateral "blow-outs" on the property. Further channel change is exacerbated by a history of local episodic and/or chronic base level lowering due to upstream progression of knickpoints from lower reaches (see

E-5 and E-6 stability assessments). A good example of this is the apparent channel incision at the Highway 88 Bridge (end of E-4 S2), where the bridge footings are exposed. These difficulties have required Stodieck to continually move his diversion structure upstream as the structures fail during moderate runoff events.

Bank Stability

S1: Moderate S2: Unstable

Bank instability in S1 is mostly associated with undercutting of levee toes on outside bends, where existing rip rap has proved ineffective or alternatively, levees went un-maintained after construction. However, the channel has a well developed and thickly vegetated terrace at the toe of the levees for 75% of its length. These terraces are providing good bank stability. Terrace heights are 5-6 feet high; un-terraced banks extend up to 10 feet from levee toe to top. Bank materials range from 48" rip rap at toes, to fairly cohesive (vegetated) small cobble and gravels. In contrast, over 55% percent of S2 banks are failing by undercutting (see above channel stability discussion); 95% of these are 1:1 to vertical. No terrace is present, nor is any stabilizing bank vegetation of any significance. Bank materials are uncohesive dozer-piled channel substrate with Dmax 12", D50 3", and D25 sand.

Vegetative Condition

Outside Levees: The historic floodplain areas in E-4 are in variable land use and condition. Scattered mature cottonwoods are found in S1 and S2; the dominant vegetative form is mostly grasses or pasture-type vegetation. S2 has some bare ground and more weeds.

Inside Levees: Channel fringe vegetation is generally abundant in S1 on terraces at levee toes. All age classes of woody vegetation are common except mature/decadent; willows to 15 feet in height; diversity is moderate. In contrast, channel banks in S2 are dominated by xeric weedy species, with very little woody riparian types; diversity is very low. Where present, woody vegetation is 25-50% browsed.

Channel Recovery And Land Management Recommendations

NOTE TO READERS:

This report was originally submitted in December of 1996, prior to the New Year's Flood of January 1997. It should be noted in reading this document that the conclusions and recommendations stated in this report are based on *observations which were made previous to the geomorphically significant flood event. The physical state of much of the observed areas has been significantly altered. In many reaches and subreaches, physical change resulting from these floods has been so significant as to render some recommendations inappropriate. Where such changes have been observed by local land managers, their opinions as to the appropriateness of recommendations should be observed. However, in our opinion, while site specific and short term recommendations may be less appropriate following the flood, general and long-term management considerations are still appropriate and relevant on a watershed scale.*

While not necessarily a channel recovery strategy, protection of infrastructure at risk is generally recognized as a first priority in unstable systems. These fall into two categories: 1) those related to threat via channel migration and, 2) threat of flooding. In terms of flooding, these risks are more difficult to identify due to the relative infrequency of the 100-year magnitude flood. In light of the above, the following general recommendations are made:

- Conduct a risk assessment to identify private and public infrastructure at risk.
- Develop river stabilization or stress alleviating schemes for areas where significant private or public infrastructure is threatened by river migration.
- Re-assess the current zoning regulations regarding future development in flood prone areas. Insure this assessment relates to an accurate and current 100-year floodplain delineation.

Regarding infrastructure protection, bear in mind that engineered solutions should focus only on at-risk infrastructure at first. Also, as with all river projects, the impacts of the stabilization or floodplain management/development schemes on the hydrologic and geomorphic behavior of the river should be fully analyzed prior to implementation. *All* stabilization schemes should follow the following best practices:

- A complete assessment of the possible effects on upstream and downstream river stability from project implementation.
- Professionally designed and engineered treatments with clearly identified factors of safety and design criteria.
- The use of treatments which will also provide benefits for fish and wildlife.
- Identification of likely failure scenarios and the anticipated costs for long-term maintenance.
- Professionally installed treatments.

To stabilize this reach of the Carson River system, one would need to: 1) consider both lateral and vertical control measures, 2) the influence of a large in-channel sediment supply and the efficient transport of that supply downstream and, 3) the effects of large floods, which the Sierra drainages are very capable of producing. All engineered approaches should adhere to the Basic Design and Engineering Standard Practices for Channel Work described on page 30 or the main text.

- Diversion Structures: We recommend that loose rock diversion structures be replaced with more permanent diversion structures or pumping galleries, in conjunction with the consolidation of diversion points to eliminate unnecessary structures. Conceptually, if the existing permanent structures could be re-engineered to allow for greater bedload transport during moderate and frequent high flow events, overall sediment transport continuity on the river may be improved. Replacement with pumping systems would allow for natural river function without the negative effects of diversion structures. The benefits of improved sediment transport may be difficult to quantify, though allowing the river the "freedom" to move bedload downstream in as natural a manner as possible is consistent with aided natural recovery options
- General: The central strategy for these reaches should be to reduce the delivery sediment to the Carson River. Given the East Fork's tendency to gain width, recovery activities would likely involve increasing channel width and the construction of a floodplain which is inundated on a bi-annual basis. These efforts would involve a great deal of earth moving and stabilization of the new channel fringes, among other activities.
- S1: Manage reach for continued riparian fringe vegetation. True channel recovery is not possible due to entrenchment and floodplain development which will keep channel confined. It is recommended that diversions be consolidated and/or made permanent such that the grade will remain stable. Alternatively, a pumping gallery scheme may be more cost-effective than installation of permanent grade controls/diversions. Erosion protection on outside bends may be warranted should infrastructure become threatened following future flood events. Protection schemes should consider:
    1. Professionally designed and installed treatments including rock terrace bank toes in combination with bioengineered banks and bendway weirs.
    2. Strategies to stabilize levee toes with well installed riprap; perhaps in conjunction with the construction of a low terrace (similar to that found in stable reaches) and/or rock flow deflectors and an aggressive planting program on treated banks. Deflectors may be necessary to provide protection to the Burnell ditch, as it is vulnerable to capture by the river directly below the current diversion point.

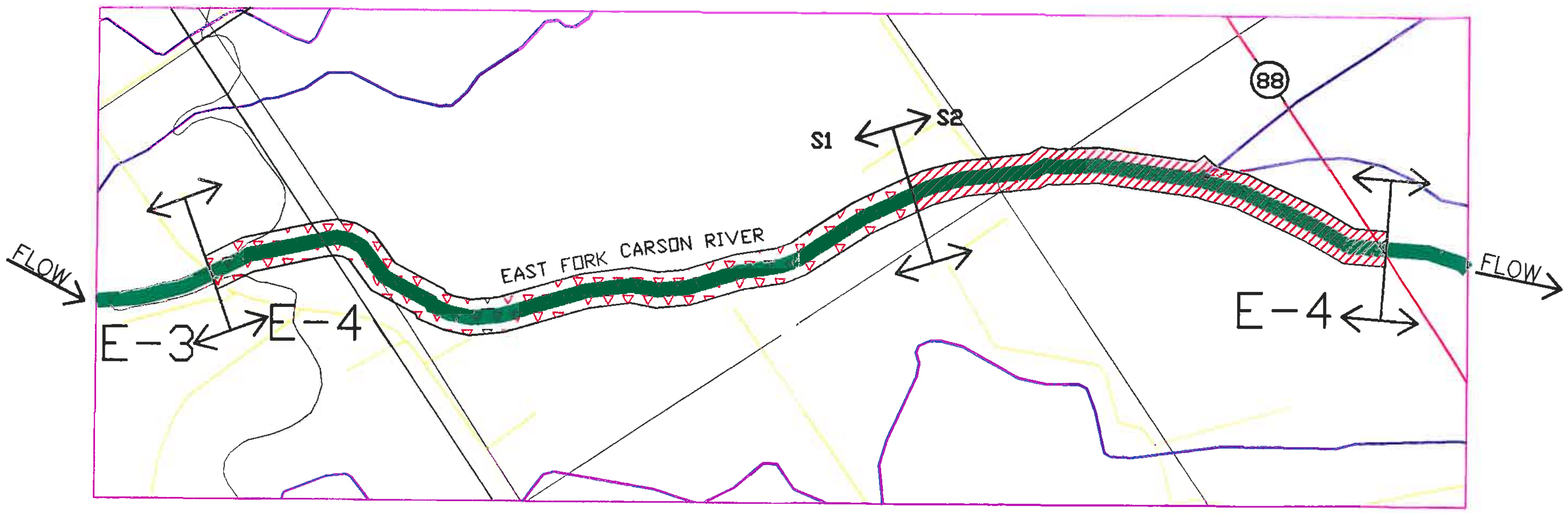
3. Active programs to remove aggraded gravel may have negative effects on existing channel-side vegetation. Any proposal of this nature should be rigorously scrutinized.

- S2: This subsection presents many challenges. Central to these will be a decision as to the cost/benefit ratio of attempts to control the rivers instability versus allowing the river to adjust on its own. Left alone, the channel will continue to laterally migrate and aggrade, assuming the diversions are maintained, precluding further down-cutting. While this would undoubtedly result in the loss of additional pasture/agricultural ground in the short-term, it should be weighed against the short- and long-term costs of mechanical channel training. In the long-term, it is possible that vegetative growth on channel fringes could coalesce into a floodplain. This process may be enhanced through an aggressive and long-term planting program. Under this scenario, attempts to control migration or to contain flood flows would not occur. If this strategy were pursued, the consequences and likelihood of large magnitude floods accessing the historic floodplain should be considered. Should structures in these areas prove vulnerable, set-back levees might be considered. A setback levee is designed to allow a river the freedom to migrate within a corridor, while still affording flood protection.

  The alternative scenario for S2 is to engage in very active channel stabilization schemes. Stabilizing the river through this subsection would involve a significant outlay of engineering design expenses, construction and long-term maintenance costs. At that, it is unclear, without further investigation, exactly what strategies would prove to be the most effective. Some strategies that could be considered include:

  - The construction of a terrace on both banks in conjunction with hidden rip rap protection on bank and/or terrace toes and extensive revegetation. The low-flow water elevations, well below even the midbank region, may stymie all but the most elaborate revegetation attempts.
  - Permanent irrigation withdrawal systems which allow for bedload transport.
  - Management of ground for woody riparian species (planned or restricted grazing) and/or more aggressive planting with rooted cuttings or containerized stock. The current NRCS revegetation work should be monitored for long-term effectiveness; they appear vulnerable to flooding in the near-term. Continual entry into the channel with heavy equipment will preclude riparian recovery, as is now the case.

- Supplemental Note: Fred Stodieck provided valuable information on his reach of the river and showed great interest in better approaches to river management. To date, he has spent a great deal of money and effort protecting his property and diversions. The current channel protection seems insufficient to weather future floods. Clearly, any further work on his property will benefit from support of local agency personnel and consideration of geomorphic processes at and above the property. This includes assistance with decisions regarding strategies as well as financial assistance with them.



REACH E-4

APPOX. SCALE: 1" = 1500'

NORTH

LEGEND

- CARSON RIVER
- ROADS
- MAIN ROADS
- TRIBUTARY CHANNELS/DITCHES
- CROSS SECTION

STABILITY

- EXTREMELY UNSTABLE
- UNSTABLE
- MODERATELY UNSTABLE
- STABLE
- VERY STABLE

E-5 REACH SUMMARY

SUB-REACHES: S1, S2
LOCATION: Highway 88 Bridge to Muller Lane Bridge

Geomorphic Setting

Rosgen/Downs/Harvey-Watson Classifications

S1: F4/E*/III S2: F4/D,d/NA
*Extensive channel manipulation

General

This reach has been extensively manipulated in the last several years, including significant channel grading and levee construction/reinforcement in the Spring of 1996. There is also a great deal of hydraulic, hydrologic and sediment transport information available stemming from a previous study of this reach (Lidstone & Anderson 1993).

The 1964 levee work which skipped the Stodieck property in E-4 was resumed from the Highway 88 Bridge to Muller Lane. Lidstone and Anderson (1993) calculated that sinuosity changed from 1.13 in 1938 to 1.04 by 1973. However, Lidstone and Anderson also point to episodes of channel straightening that occurred between 1938 and 1954, and a significant channel widening phase occurring between 1954 and 1964, including the period of time when the re-entry into this reach by the BOR occurred. Subsequent to this work, extensive groin and spur dike placement occurred on both banks during the late 1970's. Lidstone and Anderson (1993) note that some of the groins installed on the east bank promoted further channel erosion of the west bank. Finally, the 1983 flood resulted in the East Fork capturing the Cottonwood Slough channel.

Currently S1 is deeply incised; estimated to be up to 10 feet, when compared with the abandoned floodplain (bank heights 8-14 feet). In contrast, incision is less pronounced in S2, where bank heights run 2 to 6 feet. There is evidence of aggradation in both reaches, as evidenced by alternate/lateral and point/mid-channel depositional bars throughout. Some bar heights and forms are suggestive of developing floodplain surfaces, though the vegetative component is lacking. At low flows, channel braiding is apparent in some of S1. Our observations on aggradation coincide with the HEC-6 sediment transport model conducted in this reach by Lidstone and Anderson (1993), which suggest that the channel is largely aggradational at common flood frequencies. Maximum particle sizes run 4-6 inches, with D50's estimated at 1 to 2 inches. Channel shape runs from rectangular, to irregular, and shallow rectangular in a downstream direction.

Channel Capacity

S1: Lidstone and Anderson's (1993) HEC-2 modeling of Reach E-5 suggests that channel conveyance at the top of banks ranged from 3,500 cfs to 4,000 cfs. Using their flood frequency information, these discharges fall between the 2- and 5-year return interval flows. Our analysis of far fewer cross-sections using at-a-section hydraulic estimates suggest that the channel (post-spring 1996 work) exceeds bankfull at greater than the 100-year discharge (10,930 cfs). Recent channel enlargement by mechanical means has enlarged the cross-sectional area to such an extent that there is only a 3 foot difference between the 2-year and 100-year stages. Currently, the 100-year flood stage is between 2 and 4 feet below the top of the newly constructed gravel berms (loosely constructed levees).

Land Use

Grazing and agriculture are the dominant land uses, though urban development has encroached on the floodplain (see FEMA Flood Insurance Study for Douglas Co. 1983).

Relative Stability

Extremely Unstable to Unstable

General

Reach E-5 was judged to be extremely unstable to unstable due to:

- the likelihood of further channel widening
- the possibility of continued and more severe aggradation
- high percentage of vertical, steep and/or failing banks
- extreme erodability and instability of existing channel work
- absence of stabilizing riparian vegetation.

Regarding grade stability, Lidstone and Anderson (1993) suggest that one knickpoint was observed in S2 during 1993, but that overall, the channel bed was resistant to further incision due to bed armoring. Though we did not observe the aforementioned knickpoint, our observations also suggested that the channel grade had reached its lowest level, and that if anything, the channel was beginning to aggrade. It is quite possible that the knickpoint observed in 1993 has been obscured by aggradation since that time. Our independent evaluation of the reach also concurs with Lidstone and Anderson (1993) that this reach is in a dynamic transition state. Short of hardening all banks through the reach, the channel will likely laterally erode to approximate historic widths. Historic channel widths are not known conclusively, though 1938 aerial photographs suggest that active channel widths approached 400 to 600 feet in some areas. It is not known whether these measured widths were evidence of channel degradation at that time or whether they are reflective of an equilibrium state of the East Fork.

Bank Stability

S1: Unstable S2: Unstable

In S1, the average bank is 10 feet high and 1:1 to vertical, composed largely of uncohesive heterogeneous small cobble, gravel, and sand. Approximately 35% of the banks range from 1:1 to 2:1. Almost 100% of the banks are without vegetation of any type, reflective of high annual erosion and recent bank and channel manipulation with heavy equipment. The dominant mode of bank failure is from undercutting. The constructed cobble levee is actively eroding along the toe, and will be highly susceptible to future erosion from even moderate flood flows. S2 banks range from 2 to 6 feet, averaging 4 feet. Banks slopes and bank material are similar to that in S2; these banks are also completely unvegetated, undercutting, and prone to future erosion.

In both sub-reaches, rock jetty structures are present. S1 jetty's appear in good repair but not totally sufficient to arrest further erosion. In S2, the older jetty Structures Are Falling Apart; Newer Structures Near Muller Lane Are In Good Repair.

Vegetative Condition

Outside Levees: The historic floodplain areas in E-5 are in predominantly range land condition, with almost a total absence of mature woody vegetation.

Inside Levees: There is virtually no channel fringe, bank, or bar vegetation. Absence of channel fringe vegetation common in upstream reaches may be due to both heavy equipment in the channel as well as an insufficient wetted fringe. The existing channel is so wide in this reach that low flows, such as those observed in October, are incapable of saturating even mid channel bars. Some seedling cottonwoods were observed in mid-channel areas prone to future scour. Many dead seedlings were also observed on higher bars, again suggesting that flow depletions may be inhibiting seedling survival.

Channel Recovery And Land Management Recommendations

NOTE TO READERS:

This report was originally submitted in December of 1996, prior to the New Year's Flood of January 1997. It should be noted in reading this document that the conclusions and recommendations stated in this report are based on observations which were made previous to the geomorphically significant flood event. The physical state of much of the observed areas has been significantly altered. In many reaches and subreaches, physical change resulting from these floods has been so significant as to render some recommendations inappropriate. Where such changes have been observed by local land managers, their opinions as to the appropriateness of recommendations should be observed. However, in our opinion, while site specific and short term recommendations may be less appropriate following the flood, general and long-term management considerations are still appropriate and relevant on a watershed scale.

While not necessarily a channel recovery strategy, protection of infrastructure at risk is generally recognized as a first priority in unstable systems. These fall into two categories: 1) those related to threat via channel migration and, 2) threat of flooding. In terms of flooding, these risks are more difficult to identify due to the relative infrequency of the 100-year magnitude flood. In light of the above, the following general recommendations are made:

- Conduct a risk assessment to identify private and public infrastructure at risk.
- Develop river stabilization or stress alleviating schemes for areas where significant private or public infrastructure is threatened by river migration.
- Re-assess the current zoning regulations regarding future development in flood prone areas. Insure this assessment relates to an accurate and current 100-year floodplain delineation.

Regarding infrastructure protection, bear in mind that engineered solutions should focus only on at-risk infrastructure at first. Also, as with all river projects, the impacts of the stabilization or floodplain management/development schemes on the hydrologic and geomorphic behavior of the river should be fully analyzed prior to implementation. *All* stabilization schemes should follow the following best practices:

- A complete assessment of the possible effects on upstream and downstream river stability from project implementation.
- Professionally designed and engineered treatments with clearly identified factors of safety and design criteria.

- The use of treatments which will also provide benefits for fish and wildlife.
- Identification of likely failure scenarios and the anticipated costs for long-term maintenance.
- Professionally installed treatments.

To stabilize this reach of the Carson River system, one would need to: 1) consider both lateral and vertical control measures, 2) the influence of a large in-channel sediment supply and the efficient transport of that supply downstream and, 3) the effects of large floods, which the Sierra drainages are very capable of producing. All engineered approaches should adhere to the Basic Design and Engineering Standard Practices for Channel Work described on page 30 or the main text.

- Active programs to remove aggraded gravel may have negative effects on existing channel-side vegetation. Any proposal of this nature should be rigorously scrutinized.
- Erosion protection on outside bends may be warranted should infrastructure become threatened following future flood events. Protection schemes should consider:

  1. Professionally designed and installed treatments including rock terrace bank toes in combination with bioengineered banks and bendway weirs.
  2. Strategies to stabilize levee toes with well installed riprap; perhaps in conjunction with the construction of a low terrace (similar to that found in stable reaches) and/or rock flow deflectors and an aggressive planting program on treated banks. Deflectors may be necessary to provide protection to the Burnell ditch, as it is vulnerable to capture by the river directly below the current diversion point.
  3. The construction of a terrace on both banks in conjunction with hidden rip rap protection on bank and/or terrace toes and extensive revegetation. The low-flow water elevations, well below even the midbank region, may stymie all but the most elaborate revegetation attempts.

- Highway 88 Bridge. Pier footings are exposed on the bridge currently, suggesting recent (post bridge installment) local base level instability. It is unclear whether the bed is still degrading in this area, though upstream and downstream instability is high, warranting investigation of bridge safety during large floods.
- Muller Lane Bridge. Emergency work in the Spring of 1995 included the installation of flow deflectors on the left upstream bank. Channel instability is locally high, and combined with an apparently undersized

bridge (does not appear to convey flows even as large as experienced in 1996) and exposed pier footings, suggests that the river may prove to be unpredictable in this area, possibly resulting in further pier and abutment scour and threats to overall stability.

- Diversion Structures: We recommend that loose rock diversion structures be replaced with more permanent diversion structures or pumping galleries, in conjunction with the consolidation of diversion points to eliminate unnecessary structures. Conceptually, if the existing permanent structures could be re-engineered to allow for greater bedload transport during moderate and frequent high flow events, overall sediment transport continuity on the river may be improved. Replacement with pumping systems would allow for natural river function without the negative effects of diversion structures. The benefits of improved sediment transport may be difficult to quantify, though allowing the river the "freedom" to move bedload downstream in as natural a manner as possible is consistent with aided natural recovery options
- General: The central strategy for these reaches should be to reduce the delivery sediment to the Carson River. Given the East Fork's tendency to gain width, recovery activities would likely involve increasing channel width and the construction of a floodplain which is inundated on a bi-annual basis. These efforts would involve a great deal of earth moving and stabilization of the new channel fringes, among other activities.
- S1: There will be no simple solution for stabilization of all of S1. Virtually every foot of channel would need to be protected under any scheme. A series of alternate bank flow deflectors or bendway-type weirs may be considered, bearing in mind Lidstone and Anderson's observations that previous jetties have had unplanned negative consequences on opposite banks. Alternative stabilization schemes could include the construction of a compound channel enhanced by buried jetties, in combination with levee rock toes and bioengineered upper banks. Terrace elevations should be sized such that they inundate during 2- to 5-year floods. Terraces should be aggressively planted with woody riparian species. Irrigation may be necessary for establishment due to the low-flow regimes.

The above stabilization schemes, while addressing bank failure, do not address issues of aggradation or potential degradation. Without further study, it is impossible to predict the effects of artificially constraining the channel from further widening. Clearly, fixing channel width with control structures will have some impact on the manner in which the channel adjusts to the sediment and hydrologic regime. In other words, actions in Reach E-5 will likely have some influence on both E-4 and E-6, as those will adjust in kind. Possible adjustments include aggradation or degradation as the sediment supply and/or base level changes in E-5 due to the imposed changes.

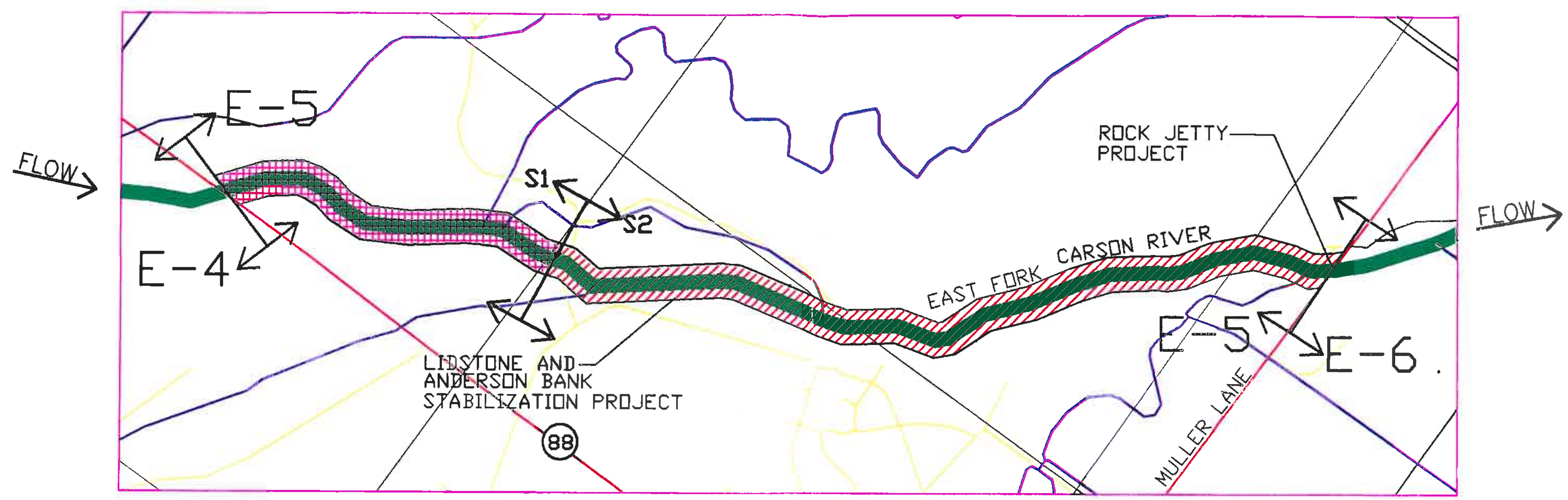
An alternative to all the above schemes is to allow the river to make lateral adjustments up to a point where current nearby infrastructure is not threatened. This may include a scheme similar to that installed by landowners adjacent to E-5, which is essentially a rip rap cutoff wall buried in the floodplain, as designed by Lidstone and Anderson (1993). The land on the west bank is likely not suitable for development due to its floodprone nature, so no direct consequences would occur should the channel migrate in that direction.

- S2: Due to the fact that bank heights are less steep in this section, any proposed bank stabilization work would likely be cheaper. The same strategies discussed for S1 are applicable here; so are the caveats regarding effects channel stabilization work might have on up or downstream reaches. For example, reach E-6 is deeply incised. As part of a long-term channel recovery strategy, this reach may need to aggrade in addition to gaining more width to further spread flood energy. If the eroding banks in E-5 are a potential sediment source for E-6, eliminating the supply from E-5 may be contrary to recovery of E-6. Finally, there is no infrastructure in need of protection below the rip-rapped banks designed by Lidstone and Anderson (1993), leading to questions as to whether this reach should be an immediate priority with available funding. Regarding that project (in S1), it appears professionally designed and installed, though it did not take advantage of bioengineering opportunities that would ultimately result in a more naturally appearing and biologically productive riparian area. Vegetation planted on the top of the banks in this project were completely dead during our inventory. This again points to the importance of appropriate plant stock, installation by qualified revegetation persons, and the need for supplemental irrigation for any bioengineered bank stabilization project.

Supplemental Note

Reach E-5 demonstrates two totally different approaches to channel stabilization. Reach S1 channel work this spring appears to have been designed to enlarge channel capacity by direct gravel removal and the containment of flood flows through gravel levee construction. The downstream work in S2 utilized extensive engineering design principles to develop a hard armored bank. As noted previously, the S1 work does not appear to be of sufficient design to withstand significant channel erosion during a future flood. In contrast, the rip rap work will have a much higher likelihood of doing so. Though it is not known for certain, it is likely that the

S2 channel design and implementation was many times more expensive than that in S1. The observation here is that well designed and installed measures are frequently expensive but more likely to survive floods. We have outlined (above) other alternatives to these previous two approaches.



REACH E-5

APPOX. SCALE: 1" = 1500'

NORTH

LEGEND

- CARSON RIVER
- ROADS
- MAIN ROADS
- TRIBUTARY CHANNELS/DITCHES
- CROSS SECTION

STABILITY

- EXTREMELY UNSTABLE
- UNSTABLE
- MODERATELY UNSTABLE
- STABLE
- VERY STABLE

E-6 REACH SUMMARY

SUB-REACHES: N A
LOCATION: Muller Lane to Genoa Bridge

Geomorphic Setting

Rosgen/Downs/Harvey-Watson Classifications

F5/E/III

General

Reach E-6 is an entrenched and straight reach. While there is no evidence of active channelization (lacking excavation spoil material adjacent to channel), it is clear that the channel is channelized, as evidenced by its extremely straight corridor with right angle bends. Furthermore, there is ample evidence, in both aerial photos and on the ground, of historic meander patterns and scars. It is possible that this reach was at one time a significant ditch which captured the channel over time, thereby allowing for channelization and incision without spoil material. Aerial photos dated back to 1938 show little change in channel planform over time, except in the low flow channel, which is actively migrating in many areas.

Three diversion and grade control structures in the reach have failed either through undermining or lateral erosion around the structures. Sediment transport dynamics of the sub-reach appear to have been affected both by aggradation behind them prior to failure as well as an oversupply of sediment directly below. Channel braiding and widening is evident below each of the failed structures. However, the grade in sections below failed structures appears to be stable, relative to its overall entrenched condition. A low flow channel within the entrenched, rectangular channel is meandering and causing bank erosion throughout the reach, though in some areas terraces are forming within the channel.

Channel Capacity

Two cross-sections were surveyed in fairly close proximity in the middle of E6. Together, they indicate a wide range in maximum channel capacity of the reach. One section contains flows only up to the 5-year discharge, while the other contains the 100-year flow. However, within the incised and enlarged channel, there exists a low-flow channel with lateral and point bars and terraces. The elevations of these in both cross-sections are roughly equivalent with the stage of a 1.25-year flow, indicating the channel may attempting to create a floodplain at this elevation within the larger channel.

Land Use

Land use throughout E-6 is sparsely vegetated rangeland.

Relative Stability

Moderately Unstable

General

While there is ample evidence of channel incision and knickpoint progression through aggradational areas behind failed channel grade structures, there is little evidence of current grade instability. The channel does appear relatively unstable from a planform perspective, as evidenced by eroding banks throughout the reach. Bar forms include point, mid-channel, and alternate bars. Mid-channel bars are generally associated with localized aggradation below failed channel structures. Other bars are indicative of channel migration and channel lengthening. In some sections, terraces have developed at the toe of vertical banks and are vegetated, indicating that the channel is developing an incipient floodplain within the entrenched channel at an elevation related to near annual maximum flows. However, the large sediment supply from upstream failing banks, channel energy during floods and lateral channel instability may preclude these features from being persistent. The sequence of natural recovery of incised channels frequently points to a phase when lateral and point bars evolve into floodplain surfaces. However, it is not likely that this form of natural recovery will take place until the channel widens to a point where flood energy over the emerging terraces becomes less intense and more amenable for persistent fine grained material deposition and vegetative establishment.

Bank Stability

Extreme Instability

Nearly 100 percent of banks in E-6 are 1:1 or steeper, void of vegetation, and susceptible to erosion during annual high flows. Erosion appears to be caused by undercutting and basal cleanout in combination with severe grazing and trampling impacts. Bank materials are sand and silt, with some clay lenses, which in some cases are acting as hard toes and slowing the rate of channel migration. The bottom section of E-6, however, has been fenced off from grazing and exhibits greater bank stability, largely as a result of moderate riparian vegetation and no trampling of banks by cattle.

Vegetative Condition

Vegetation condition throughout E-6 is sparse range land with effectively no riparian vegetation or riparian corridor. Vegetation is predominantly sage brush and rabbit brush with some isolated areas of irrigated pasture. The vegetation condition is a significant contributor to bank instability throughout the reach.

Channel Recovery And Land Management Recommendations

NOTE TO READERS:

This report was originally submitted in December of 1996, prior to the New Year's Flood of January 1997. It should be noted in reading this document that the conclusions and recommendations stated in this report are based on observations which were made previous to the geomorphically significant flood event. The physical state of much of the observed areas has been significantly altered. In many reaches and subreaches, physical change resulting from these floods has been so significant as to render some recommendations inappropriate. Where such changes have been observed by local land managers, their opinions as to the appropriateness of recommendations should be observed. However, in our opinion, while site specific and short term recommendations may be less appropriate following the flood, general and long-term management considerations are still appropriate and relevant on a watershed scale.

While not necessarily a channel recovery strategy, protection of infrastructure at risk is generally recognized as a first priority in unstable systems. These fall into two categories: 1) those related to threat via channel migration and, 2) threat of flooding. In terms of flooding, these risks are more difficult to identify due to the relative infrequency of the 100-year magnitude flood. In light of the above, the following general recommendations are made:

- Conduct a risk assessment to identify private and public infrastructure at risk.
- Develop river stabilization or stress alleviating schemes for areas where significant private or public infrastructure is threatened by river migration.
- Re-assess the current zoning regulations regarding future development in flood prone areas. Insure this assessment relates to an accurate and current 100-year floodplain delineation.

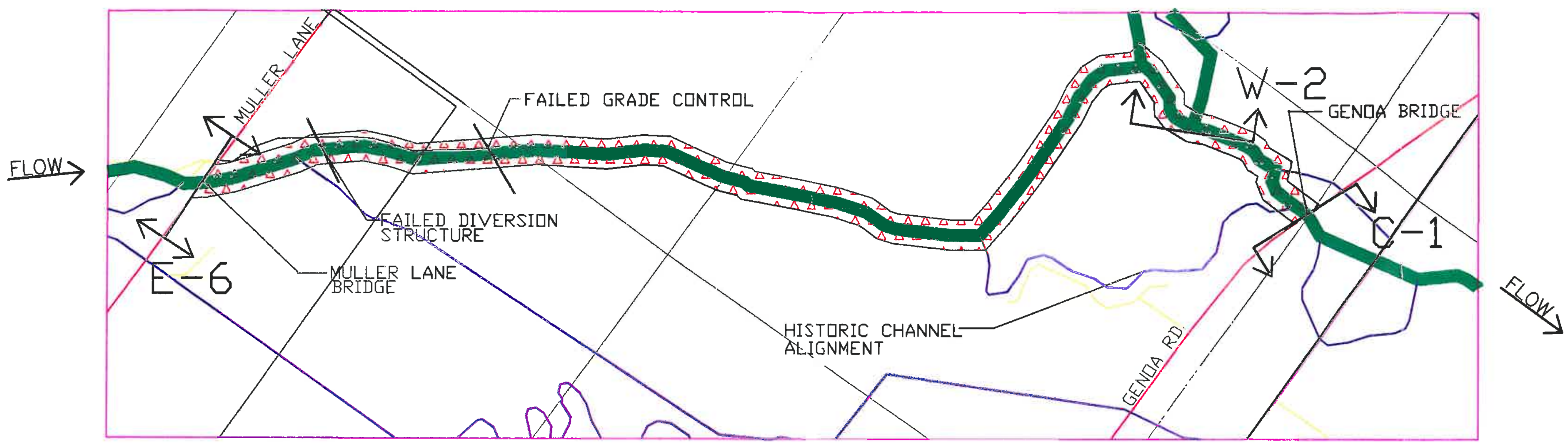
Regarding infrastructure protection, bear in mind that engineered solutions should focus only on at-risk infrastructure at first. Also, as with all river projects, the impacts of the stabilization or floodplain management/development schemes on the hydrologic and geomorphic behavior of the river should be fully analyzed prior to implementation. *All* stabilization schemes should follow the following best practices:

- A complete assessment of the possible effects on upstream and downstream river stability from project implementation.
- Professionally designed and engineered treatments with clearly identified factors of safety and design criteria.
- The use of treatments which will also provide benefits for fish and wildlife.
- Identification of likely failure scenarios and the anticipated costs for long-term maintenance.
- Professionally installed treatments.

To stabilize this reach of the Carson River system, one would need to: 1) consider both lateral and vertical control measures, 2) the influence of a large in-channel sediment supply and the efficient transport of that supply downstream and, 3) the effects of large floods, which the Sierra drainages are very capable of producing. All engineered approaches should adhere to the Basic Design and Engineering Standard Practices for Channel Work described on page 30 or the main text.

- Genoa Bridge. This bridge appears to be undersized, and given the large in-channel sediment supply upstream, there could be future problems with local aggradation and abutment scour during large floods. All Genoa Lane bridges crossing the Carson and Brockliss are particularly at risk if considering the potential for significant channel shifts above these bridges.
- Land management and channel recovery recommendations are limited to riparian grazing management. Due to the absence of development in this area, there is little reason to recommend active channel recovery projects until upstream instability and sediment supply is addressed. The grade appears relatively stable, and lateral migration is predominantly within the entrenched channel. If stream corridor fencing is implemented, it should be set back at such a distance that allows for vegetative growth well outside of the channel. In such a scenario, lateral migration and bank failure will be backed by existing vegetation.
- Grade control in this reach may be useful to raise the bed relative to the floodplain and promote vegetation growth in a stream corridor. However, in light of past failed structures, any such activities should carefully scrutinized and designed. Such a strategy would be largely experimental and would undoubtedly have implications for further bank erosion between structures. Furthermore, more numerous structures will be required to raise the channel bed throughout the reach than were

implemented previously. Such structures would trap bedload from bank erosion and upper reaches, thereby reducing sediment supply to lower reaches (C-1). Due to the current excess sediment supply in C-1, however, this should not be a concern.



REACH E-6

APPOX. SCALE: 1" = 1500'

NORTH

LEGEND

- CARSON RIVER
- ROADS
- MAIN ROADS
- TRIBUTARY CHANNELS/DITCHES
- CROSS SECTION

STABILITY

- EXTREMELY UNSTABLE
- UNSTABLE
- MODERATELY UNSTABLE
- STABLE
- VERY STABLE