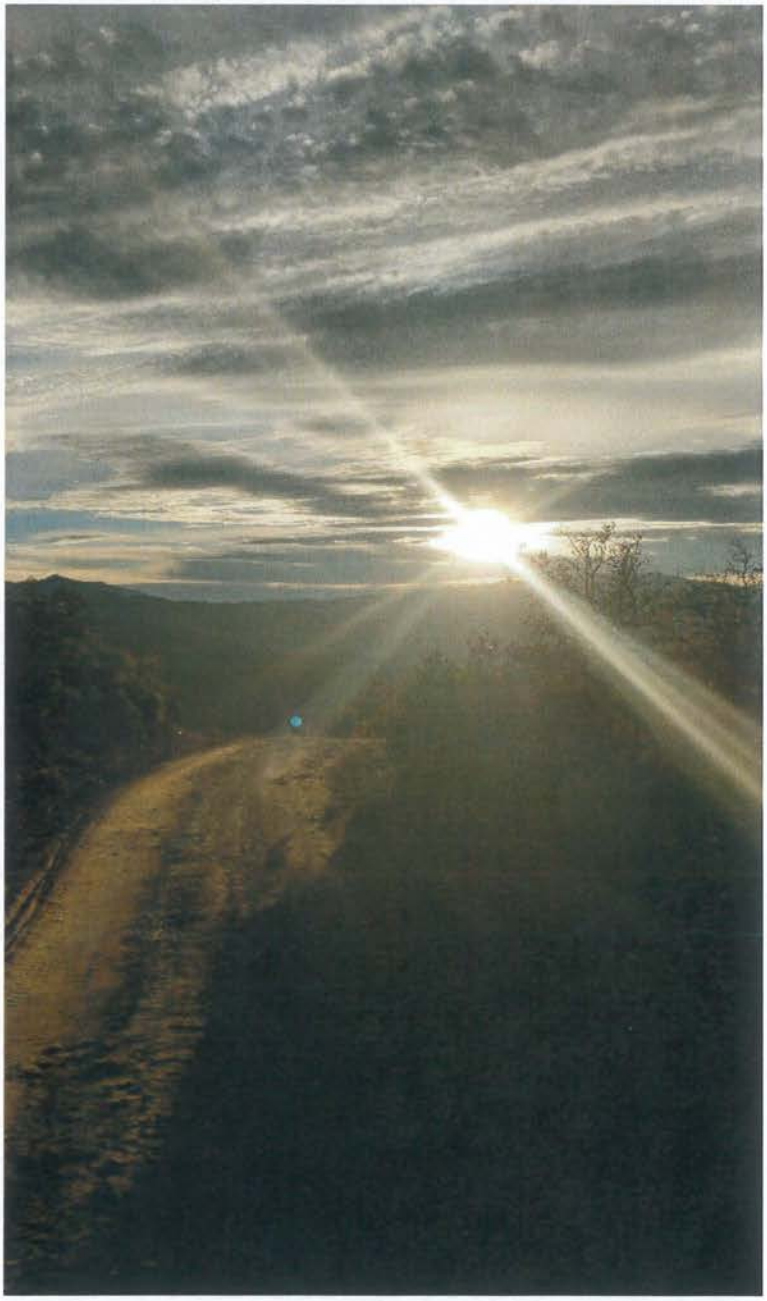

ROAD ASSESSMENT

Timberland Resource Consultants

Prepared by:

Chris Carroll

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165 South Fortuna Blvd

Fortuna, CA 95540

Cobb Road Association – Road Assessment
April 30, 2020

Purpose

This road assessment has been prepared at the request of the Cobb Road Association as a supplement to the Lake and Streambed Alteration Notification (LSA). During preparation of the LSA, it became evident that some of the watercourse crossings planned for upgrade were receiving runoff from lengthy sections of road surfaces and inside ditches. The purpose of this road assessment is to identify locations for proposed road surface drainage and inside ditch cross-drains in order to hydrologically disconnect road runoff from the watercourse crossing inlets and outlets and to disperse concentrated runoff.

Scope

This road assessment covers approximately 1.1 miles of Cobb Road and 500 feet of Rattlesnake Bridge Road, beginning at the intersection with Rattlesnake Bridge Road and Highway 36. The short section of Rattlesnake Bridge Road is included in the assessment because it receives surface runoff from Cobb Road and it was included in a recent Notice of Violation issued by the California Dept. of Fish and Wildlife to a parcel owner and Cobb Road Association member. The section of the road assessed is shown on the attached maps. The road assessment focuses primarily on the condition and functionality of road surface and ditch drainage features, and was conducted using standards and procedures found in the *Handbook for Forest, Ranch and Rural Roads.* Where the assessment has determined that improvements along the road are required, the report will recommend upgrades consistent with best management practices.

Methods

The initial assessment was conducted under relatively dry conditions on 4-24-2020. Most of the road surface was approximately 12 to 14 feet wide with numerous wider turnouts to allow for parking or passing of oncoming vehicles. The road segment that was assessed crosses or borders 13 separate, private parcels that are members of the Cobb Road Association. The road receives moderate traffic use and it appears that landowners keep up on road maintenance in the form of surface rocking and grading. The surface appeared to contain enough rock to allow for winter time vehicle use. The majority of the road is insloped to crowned. The road lacks adequate cross-draining of the inside ditch to avoid excessive concentration of runoff and hydrologic connectivity at the watercourse crossings.

Where the assessment has determined that improvements are needed along the road, the report recommends upgrades to be applied consistent with best management practices (BMPs). Descriptions and/or recommendations given at individual road points or road segments are stated below. Road Points 1 through 16 are watercourse crossings. Watercourse crossing condition, functionality, proposed upgrades, and culvert sizing calculations are discussed in depth in this LSA Notification, and therefore are not being repeated in this assessment. In this road assessment the watercourse crossings are referenced and considered with regards to proposed and existing road surface drainage features. Road Points ending with the letter A through H are individual Road Points that are described below. Road recommendations are based on the conditions observed on the date of the assessment, and may require modifications due to changes in the condition of the road in the future. Recommendations did not take into account private property landowners along the road, or any required permits that must be obtained prior to road work.

Road Points / Segments

Road Segment 1 to 3: Road Segment is the heavily blacktopped, 500-foot long section of Rattlesnake Bridge Road. It was included in the assessment because it receives runoff from Cobb Road and it was included in a recent CDFW, Notice of Violation Letter to a Cobb Road Association landowner for "Sediment delivery from failing culvert". Road Points 1, 2, and 3 are existing watercourse crossings that are described in this LSA Notification. The road surface is intact and does not require surface maintenance at this time. The outlet of the crossing at Road Point 2 currently receives road surface runoff and sediment from the road upslope of Road Point 3, beyond the blacktopped surface.

Road Point 3A: At Road Point 3 the blacktopped surface ends and the road surface is rocked. The road at the intersection of Cobb Road with Rattlesnake Bridge Road lacks a defined surface drainage pattern and has minor surface ruts from runoff. Runoff from both roads comes together at Road Point 3A, flows onto the blacktopped section at Road Point 3, and then fans along the outer edge and is delivered over the outlet at Road Point 2.

At Road Point 3A, grade the surface and add rock as necessary to establish a crowned drainage pattern from the end of the blacktop, through the intersection and up Cobb Road to the right. Keep runoff contained to the road side edges and off of the running surface. Establish a rocked rolling dip across the road surface of Rattlesnake Bridge Road to contain Cobb Road inside ditch runoff. Through the watercourse crossing at Road Point 3, the road has established berms on both sides of the road that keeps road runoff from entering watercourse. Establish roadside ditches on both sides of the road through Road Point 3, with as little vegetation disturbance as possible. The inside ditch from Road Point 3 to Road Point 2 is low gradient, wide and covered with thick grass. On the outside edge, establish a lead-out ditch at Road Point 2A to disperse the outside ditch runoff into grass and vegetation below the road rather than being carried down the road and over the outlet at Road Point 2.

Road Point 4A: Road surface between the crossings at Road Point 4 and 5 is rocked and has a partially crowned surface with a rocky inside ditch. The inside ditch connects to the inlet of the watercourse crossing at Road Point 4. Some of the road surface runoff delivers to the inlet and some of it travels over the road, past the crossing. At Road Point 4A, install a diagonal rocked rolling dip at the shallow ditch location to drain the inside ditch and the road surface.

Road Segment 5 to 6: This is a short section of road between the two watercourse crossings. The segment has a lightly crowned surface. Along Segment 5 to 6 keep the road surface maintained with a rocked surface. During future grading, work towards outsloping this section of road.

Road Segment 6 to 7: This is a lengthy segment of crowned road with an inside ditch that drains to the inlet of the crossing at Road Point 6. At Road Points 6A and 6B, install rocked rolling dips or ditch relief culverts to drain the inside ditch. Approximately 5 years ago, the watercourse crossing at Road Point 7 plugged due a landslide leaving a gully over the inlet, and a second narrow gully approximately 120 feet to the west that led from the road back down to the watercourse. At Road Point 6C install a rocked rolling dip approximately 30 feet west of the second gully.

Road Segment 7 to 8: The watercourse crossing at Road Point 7 plugged due to a landslide approximately 5 years ago leaving the culvert intact but leaving an eroded a gully over the crossing fill. The watercourse crossing at Road Point 8 is a very small Class III watercourse that diverts into the inside ditch and is carried to the inlet of the crossing at Road Point 7 during heavy rain. A bank seep begins approximately 100 feet south of Road Point 8. This entire road segment has a fairly level grade and the inside ditch is vegetated and is not eroding. The majority of the road width along this segment drains towards the outboard edge rather than towards the ditch. At Road Point 7, replace the eroded fill material with compacted fill and rock armor, and a slight berm to keep road runoff from delivering over the outlet. At Road Point 7A, install a rocked rolling dip to drain the road surface and inside ditch. At Road Point 8 install a permanent culvert per this LSA notification. The new culvert will also serve to drain the bank seep that begins approximately 100 feet to the south.

Road Segment 8A to 9: Road Point 8A and 8G are functioning 18-inch diameter ditch relief culverts. The culvert at Road Point 8A becomes overwhelmed by runoff during rains because it drains over 1,000 feet of inside ditch. This length of undrained inside ditch is also leading to downcutting along the inside ditch along the steeper sections. Proposed ditch relief locations are limited by developed sites on the parcels along the road. To relieve the ditch, at Road Point 8B install a rocked rolling dip where the inside ditch is shallow. At Road Point 8C, install an 18-inch diameter ditch relief culvert per the BMPs with rock armoring below the outlet. Road Point 8D is a point on the approach to the switchback where the inside ditch transitions from the east side of the road to the west side of the road. Runoff crosses the road at this location at an existing rocked rolling dip, keeping runoff contained to the inside ditch. This would be a natural location for a lead-out ditch, but the area is developed with a driveway, structures, and infrastructure. Above this point, at Road Point 8E and 8F, install rocked rolling dips. Upslope of the ditch relief culvert at Road Point 8G, install a rocked rolling dip at Road Point 8H.

Road Segment 9 to 10: Road segment is rocked and insloped to crowned as it switches back on a ridgetop. The inside ditch transitions to the east side of the road and it drains to the inlet of the watercourse crossing at Road Point 9. At Road Point 9A, install a rocked rolling dip or a ditch relief culvert. At Road Point 9B, install a rocked rolling dip.

Road Segment 10 to 11: Road segment is rocked and insloped to crowned and has a fairly level grade. The inside ditch drains to the watercourse crossing at Road Point 10 during rain. At Road Point 10A, install a rocked rolling dip to drain the road surface and the inside ditch. Road Point 10B is a short section of road that puddles during rain and the surface becomes soft. At Road Point 10B, apply rock to the road surface and outslope the short section so that it drains and no longer puddles on the road surface.

Road Segment 11 to 12: Road segment is rocked and insloped to crowned and has a fairly level grade. The inside ditch drains to the watercourse crossing at Road Point 11 during rain. At Road Point 11A, install a rocked rolling dip to drain the road surface and the inside ditch. Road Point 11B and 11C are locations for proposed ditch relief culverts. A wooden fence along the outboard side of the road will need to be dismantled at two locations for the installation of the proposed culverts.

Road Segment 12 to 13: Road segment is rocked and has a well graded, crowned surface. The gradient is fairly level and the inside ditch did not appear to be eroding. At Road Point 12A, install a rocked rolling dip to drain the road surface and the inside ditch. During road rocking and grading as part of future routine maintenance, the operator and road association members could explore draining this section of road by way of a more outsloped design, with more surface runoff draining towards the outboard edge and less towards the inside ditch.

Road Segment 13 to 15: Road segment from the watercourse crossing at Road Point 13 to approximately 150 feet south of the watercourse crossing at Road Point 15 is rocked and has a well graded, crowned surface. The gradient is fairly level with natural grade breaks. The inside ditch is vegetated with grass and did not appear to be eroding. The inside ditch contains a short length of bank seep west of Road Point 14. During road rocking and grading as part of future routine maintenance, the operator and road association members could explore draining this section of road by way of a more outsloped design, with more surface runoff draining towards the outboard edge and less towards the inside ditch.

Road Segment 15 to 16: Road segment from the watercourse crossing at Road Point 15 to the watercourse crossing at Road Point 16 is rocked and crowned. The gradient is fairly level with natural grade breaks. At Road Point 15A, install a rocked rolling dip to drain the road surface and inside ditch. At Road Point 15B there is an existing rolling dip. It drains road runoff from the road and also a steep driveway that approaches from the northeast. At Road Point 15B, upgrade the existing rolling dip by installing a rocked rolling dip with more rock armoring to the outfall. At Road Point 15C the road surface is crowned with an existing lead-out on the east side of the road. At Road Point 15C, maintain the existing lead-out ditch on the east side of the road, and reconstruct the lead-out ditch on the west side of the road.

Road Segment 16 to End of Road Assessment: Road segment from the watercourse crossing at Road Point 16 to the End of Road Assessment is rocked and has a crowned surface. The segment has a natural grade break. At Road Point 16A maintain the existing lead-out ditch. The End of Road Assessment comes where the road passes through a short corner of USFS property marked by a boundary sign and old blazes. The road appears to continue on downslope beyond this road assessment.

Photographs

Road Point 3 and 3A: The photos show the watercourse crossing at Road Point 3 and the road intersection at Road Point 3A. At Road Point 3A, grade the surface and add rock as necessary to establish a crowned drainage pattern from the end of the blacktop, through the intersection and up Cobb Road to the right. Keep runoff contained to the road side edges and off of the running surface. Establish a rocked rolling dip across the road surface of Rattlesnake Bridge Road to contain Cobb Road inside ditch runoff. Through the watercourse crossing at Road Point 3, the road has established berms on both sides of the road that keeps road runoff from entering watercourse. Establish roadside ditches on both sides of the road through Road Point 3, with as little vegetation disturbance as possible. Photo date 4-24-2020.

Photographs

Road Point 3 and 2A: The photos are taken from the watercourse crossing at Road Point 3 and show the view looking downslope, southerly. Establish roadside ditches on both sides of the road through Road Point 3, with as little vegetation disturbance as possible. The inside ditch from Road Point 3 to Road Point 2 is low gradient, wide and covered with thick grass beyond the pickup in the photo. On the outside edge, establish a lead-out ditch at Road Point 2A, beyond the double madrone pictured, to disperse the outside ditch runoff into grass and vegetation below the road rather than being carried down the road and over the outlet at Road Point 2. Photo date 4-24-2020.

Photographs

Road Point 4A: The photo is taken at Road Point 4A. The watercourse crossing at Road Point 5 is located at the gate in the picture. The road surface between the crossings at Road Point 4 and 5 is rocked and has a partially crowned surface with a rocky inside ditch. At Road Point 4A, install a diagonal rocked rolling dip at the shallow ditch location to drain the inside ditch and the road surface. Photo date 4-24-2020.

Photographs

Road Segment 6 to 7: These photos show the lengthy segment of crowned road with an inside ditch from Road Point 6A looking southerly towards Road Point 6B. At Road Points 6A and 6B, install rocked rolling dips or ditch relief culverts to drain the lengthy inside ditch. Photo date 4-24-2020.

Photographs

Road Segment 6 to 7: This photo shows the segment of crowned road with an inside ditch from Road Point 6C looking easterly towards Road Point 7. At Road Point 6C, install a rocked rolling dip approximately 30 feet west of the gully below the road. Photo date 4-24-2020.

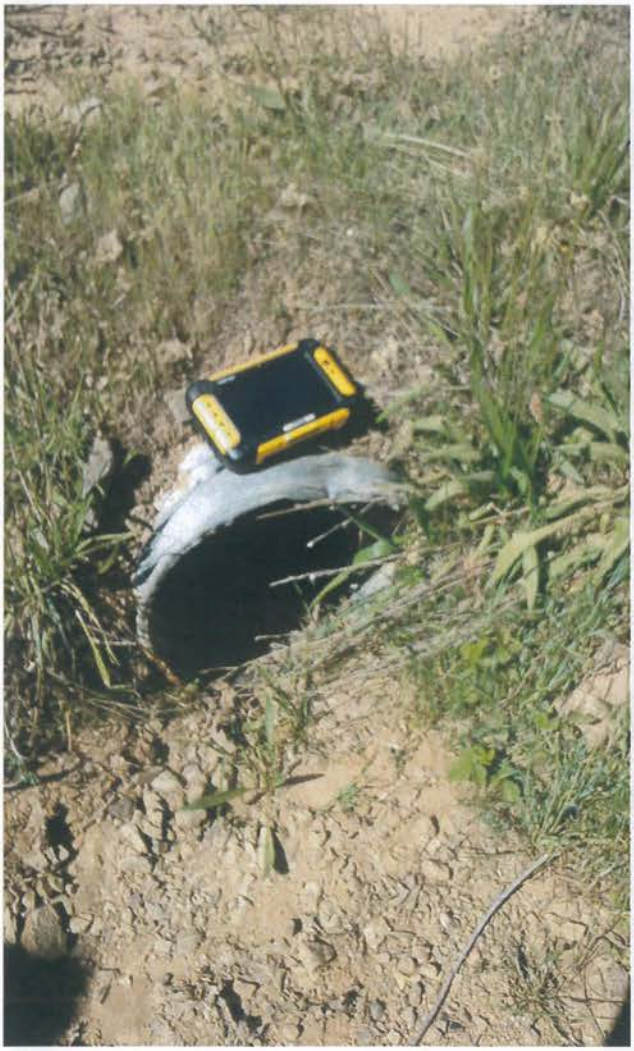
Photographs

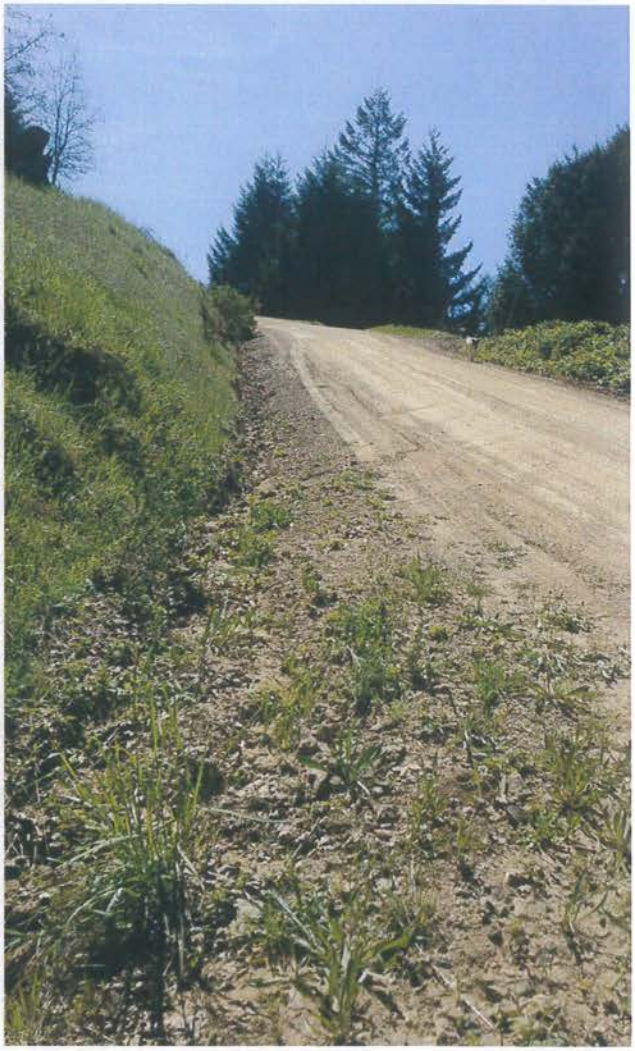
Road Point 7: This photo shows the eroded gully that remains after the watercourse crossing at Road Point 7 became plugged several years ago. At Road Point 7, replace the eroded fill with compacted fill and rock armor, and a slight berm to keep road runoff from delivering over the outlet and to gain a safe road width. Photo date 4-24-2020.

Photographs

Road Point 8: The photos were taken at Road Point 8 which is the site of the proposed culvert in the LSA Notification. The photo on the left shows the inside ditch that carries bank seep water, and flow from a small Class III watercourse during rain, towards the watercourse crossing at Road Point 7 in the distance. Halfway between Road Point 7 and 8, at Road Point 7A, install a rocked rolling dip. The photo on the right shows the same inside ditch looking upslope, southerly from Map Point 8. Photo date 4-24-2020.

Photographs





Road Segment 8A to 8H: The photo on the left shows the inlet of the functioning 18-inch diameter ditch relief culvert at Road Point 8A. The photo on the right shows the view looking up the inside ditch from the culvert inlet. Several cross-drain locations are proposed to relieve the lengthy inside ditch. Road Points 8B, 8E, 8F, and 8H are proposed rocked rolling dips locations. Road Point 8C is a proposed ditch relief culvert location. Photo date 4-24-2020.

Photographs

Road Point 8H: The photo shows the road surface from the watercourse crossing at Road Point 9 looking southerly toward the proposed rocked rolling dip location at Road Point 8H. Photo date 4-24-2020.

Photographs

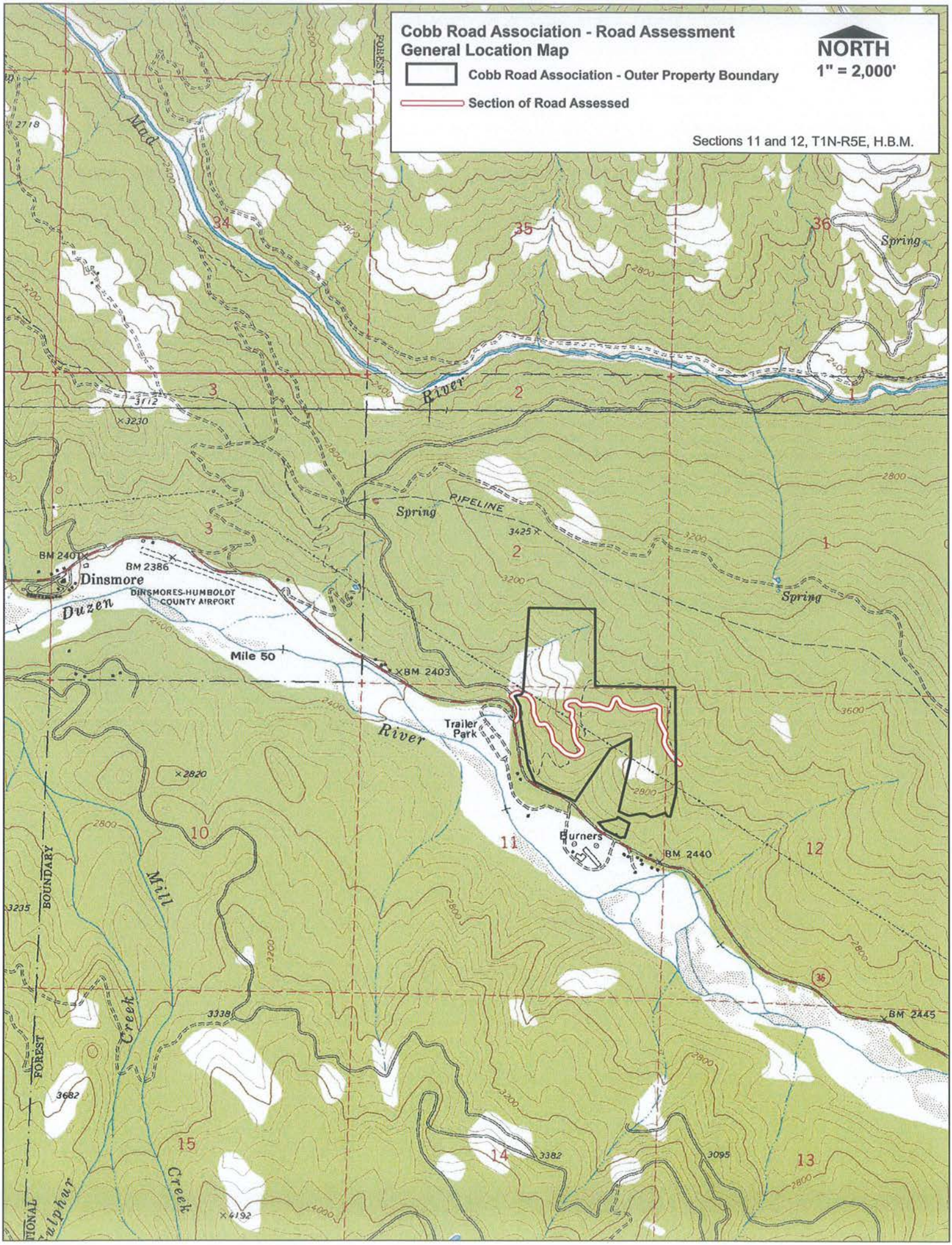
Road Point 10A: The photo shows the road surface from the watercourse crossing at Road Point 10 looking southeasterly toward the proposed rocked rolling dip location at Road Point 8H. Photo date 4-24-2020.

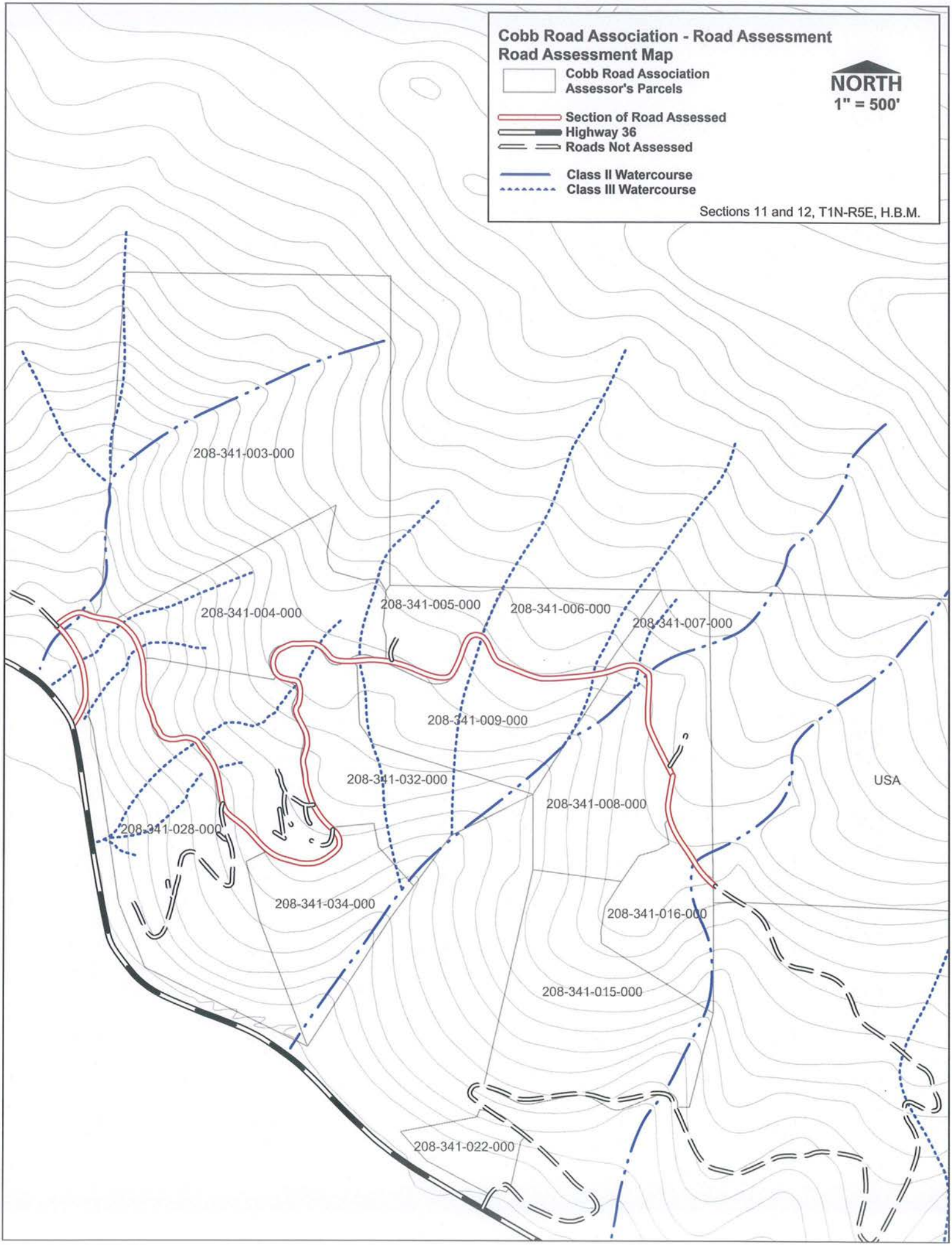
Photographs

Road Point 13: The photos were taken at the watercourse crossing at Road Point 13. The photo on top faces westerly, the photo on the bottom faces easterly. Road segment is rocked and has a well graded, crowned surface. The gradient is fairly level and the inside ditch did not appear to be eroding. During road rocking and grading as part of future routine maintenance, the operator and road association members could explore draining this section of road by way of a more outsloped design, with more surface runoff draining towards the outboard edge and less towards the inside ditch. Photo date 4-24-2020.

Photographs

Road Points 14 and 15: The photos were taken at the watercourse crossings at Road Points 14 and 15. The photo on top faces westerly, the photo on the bottom faces easterly. Road segment is rocked and has a well graded, crowned surface. The gradient is fairly level with natural grade breaks. The inside ditch is vegetated with grass and did not appear to be eroding. The inside ditch contains a short length of bank seep west of Road Point 14. During road rocking and grading as part of future routine maintenance, the operator and road association members could explore draining this section of road by way of a more outsloped design, with more surface runoff draining towards the outboard edge and less towards the inside ditch. Photo date 4-24-2020.


Cobb Road Association - Road Assessment
General Location Map
Cobb Road Association - Outer Property Boundary
Section of Road Assessed
NORTH
1" = 2,000'
Sections 11 and 12, T1N-R5E, H.B.M.
Mad River
Spring
PIPELINE
Dinsmore
DINSMORES-HUMBOLDT COUNTY AIRPORT
Duzen River
Mile 50
Trailer Park
Burners
BM 2440
BM 2445
BM 2403
BM 2386
BM 2401
Mill Creek
Sulphur Creek
BOUNDARY
FOREST
34
35
36
3
2
1
10
11
12
13
14
15


Cobb Road Association - Road Assessment
Road Assessment Map
Cobb Road Association
Assessor's Parcels
NORTH
1" = 500'
Section of Road Assessed
Highway 36
Roads Not Assessed
Class II Watercourse
Class III Watercourse
Sections 11 and 12, T1N-R5E, H.B.M.
208-341-003-000
208-341-004-000
208-341-005-000
208-341-006-000
208-341-007-000
208-341-009-000
208-341-032-000
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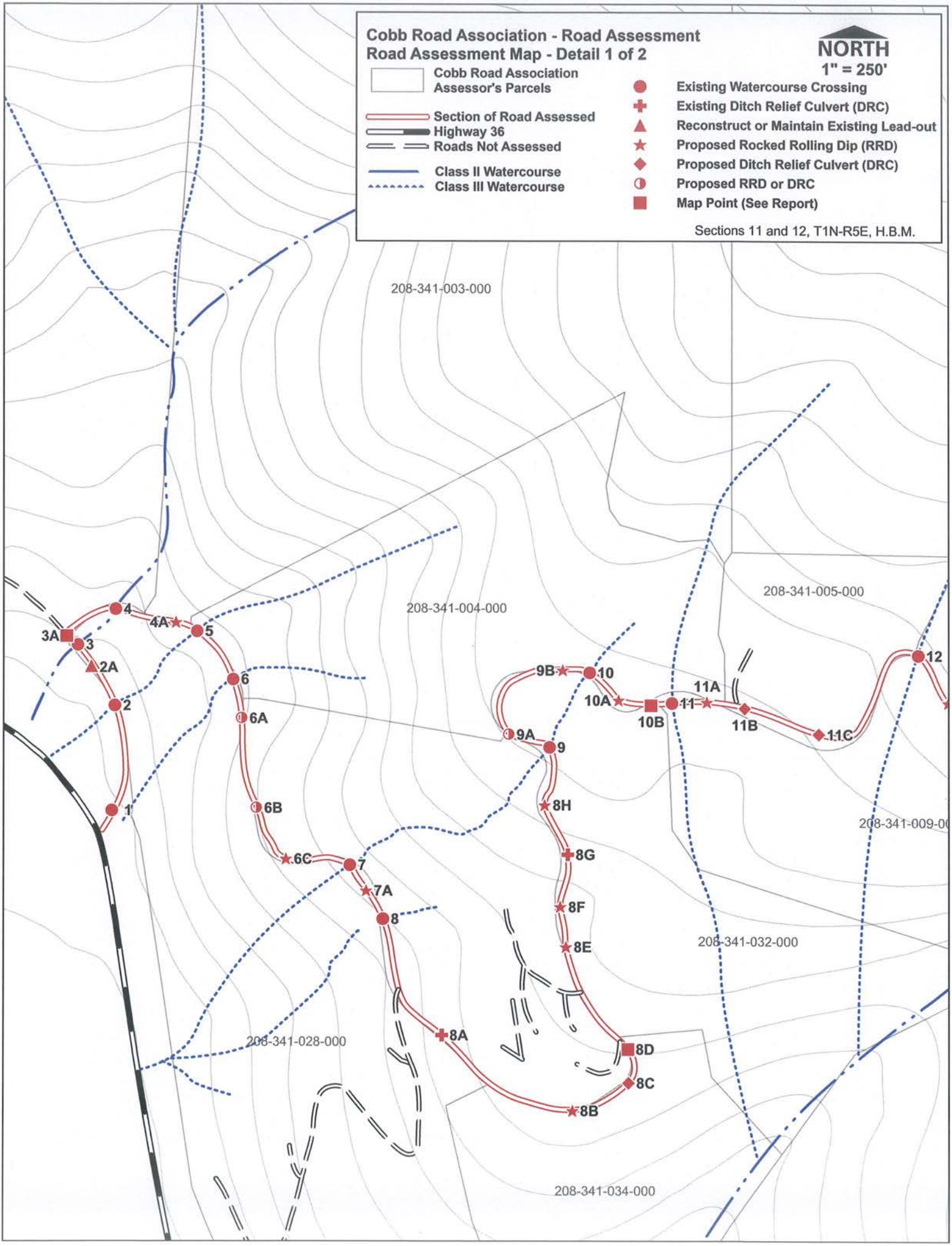
208-341-015-000
208-341-022-000
USA


Cobb Road Association - Road Assessment
Road Assessment Map - Detail 1 of 2
NORTH
1" = 250'
Cobb Road Association Assessor's Parcels
Section of Road Assessed
Highway 36
Roads Not Assessed
Class II Watercourse
Class III Watercourse
Existing Watercourse Crossing
Existing Ditch Relief Culvert (DRC)
Reconstruct or Maintain Existing Lead-out
Proposed Rocked Rolling Dip (RRD)
Proposed Ditch Relief Culvert (DRC)
Proposed RRD or DRC
Map Point (See Report)
Sections 11 and 12, T1N-R5E, H.B.M.
208-341-003-000
208-341-004-000
208-341-005-000
208-341-009-000
208-341-032-000
208-341-028-000
208-341-034-000
1
2
2A
3
3A
4
4A
5
6
6A
6B
6C
7
7A
8
8A
8B
8C
8D
8E
8F
8G
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9A
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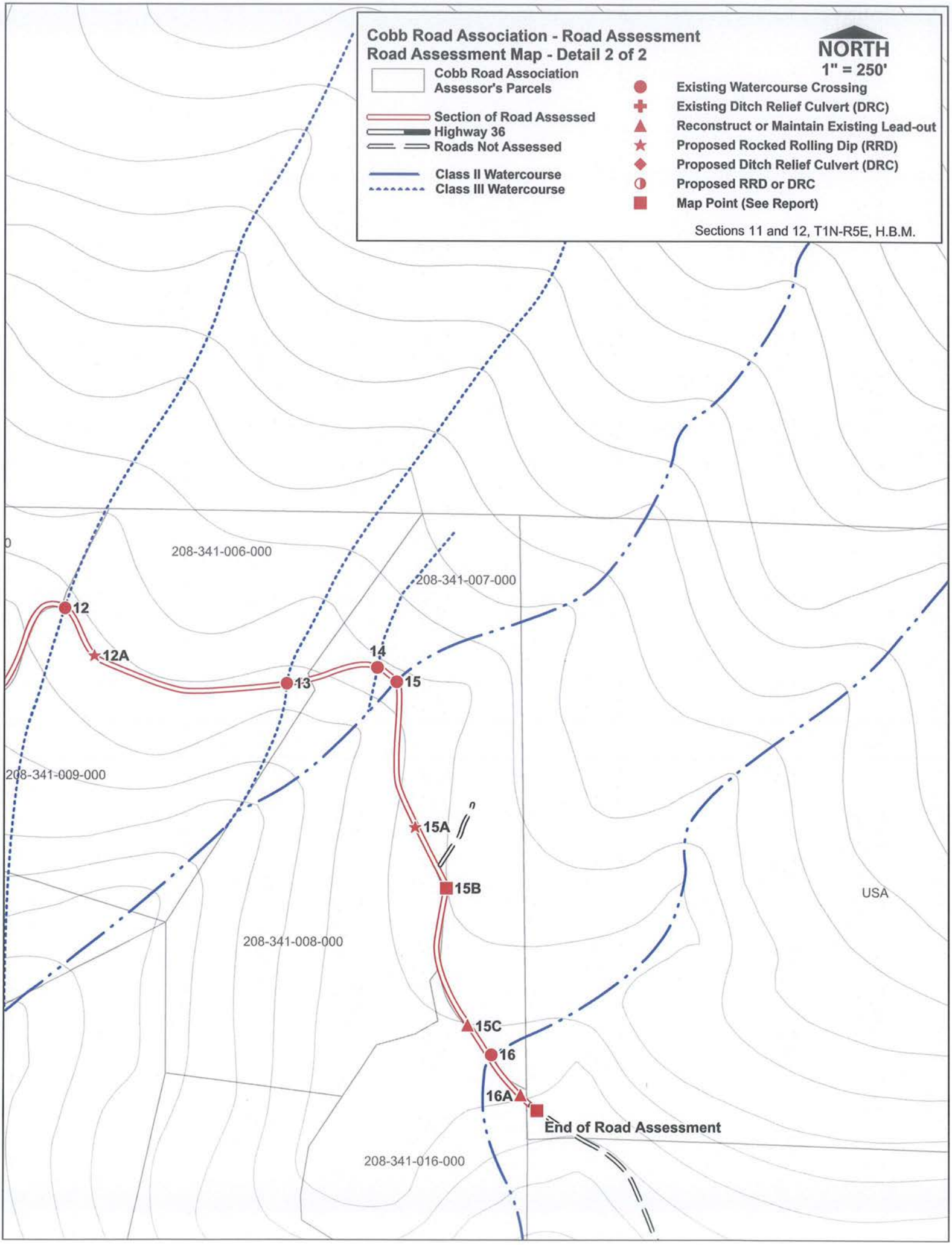
10
10A
10B
11
11A
11B
11C
12


Cobb Road Association - Road Assessment
Road Assessment Map - Detail 2 of 2
NORTH
1" = 250'
Cobb Road Association Assessor's Parcels
Section of Road Assessed
Highway 36
Roads Not Assessed
Class II Watercourse
Class III Watercourse
Existing Watercourse Crossing
Existing Ditch Relief Culvert (DRC)
Reconstruct or Maintain Existing Lead-out
Proposed Rocked Rolling Dip (RRD)
Proposed Ditch Relief Culvert (DRC)
Proposed RRD or DRC
Map Point (See Report)
Sections 11 and 12, T1N-R5E, H.B.M.
208-341-006-000
208-341-007-000
208-341-009-000
208-341-008-000
208-341-016-000
USA
12
12A
13
14
15
15A
15B
15C
16
16A
End of Road Assessment

BMP: Rolling Dip Design and Placement

- Rolling dips are drainage structures designed to force surface water to be drained from the road surface.
- The road shall dip into, and rise out of, the rolling dip to eliminate the potential of road surface runoff to run further down road way.
- The rolling dip shall be constructed with clean native materials or rock surfaced where specified.
- The rolling dips outlet may be armored to resist down-cutting and erosion of the outboard road fill.
- Do not discharge rolling dips into any areas that show signs of instability or active landsliding.
- If the rolling dip is designed to divert both road surface and ditch runoff, block the down-road ditch with compacted fill in order to force all ditch flows through the trough (low point) of the rolling dip.

BMP: Rocked Rolling Dip Design and Placement

- Rocked rolling dips are drainage structures designed to carry known sources of surface water across road ways or from known persistently wet segments of road such as swales without defined watercourses or road segments with heavy bank/road seepage.
- The road shall dip into, and rise out of, the rocked rolling dip to minimize diversion potential.
- The rocked rolling dip shall be constructed with clean rock that is large enough to remain in place during peak flows. Rock size shall vary relative to the anticipated flow through the dip with larger rock used in location where greater flow is anticipated.
- The rocked rolling dips inlet and outlet shall be armored to resist down-cutting and erosion.
- The entire width of the rocked rolling dip shall be rock armored to a minimum of 5-feet from the centerline of the dipped portion of the rolling dip.
- If a keyway is necessary, the rocked rolling dip keyway at the base of the dip shall be of sufficient size, depth and length to support materials used in the rocked rolling dip construction back up to the road crossing interface.
- Do not discharge rolling dips into any areas that show signs of instability or active landsliding.
- If the rolling dip is designed to divert both road surface and ditch runoff, block the down-road ditch with compacted fill.
- The rolling dip should be designed as a broad feature ranging from 10-100 feet long so that it is drivable by most types of vehicular traffic and not significantly inhibit traffic and road use.

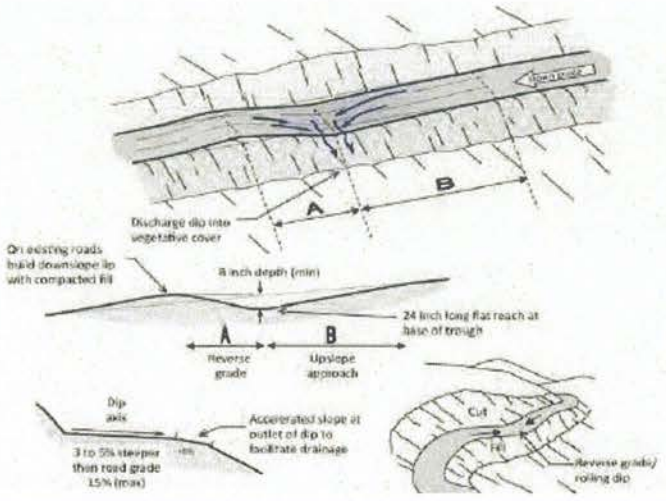


FIGURE 34. *A classic Type I rolling dip, where the excavated up-road approach (B) to the rolling dip is several percent steeper than the approaching road and extends for 60 to 80 feet to the dip axis. The lower side of the structure reverses grade (A) over approximately 15 feet or more, and then falls down to rejoin the original road grade. The dip must be deep enough that it is not obliterated by normal grading, but not so deep that it is difficult to negotiate or a hazard to normal traffic. The outward cross-slope of the dip axis should be 3% to 5% greater than the up-road grade (B) so it will drain properly. The dip axis should be out-sloped sufficiently to be self-cleaning, without triggering excessive downcutting or sediment deposition in the dip axis (Modified from: Best, 2013).*

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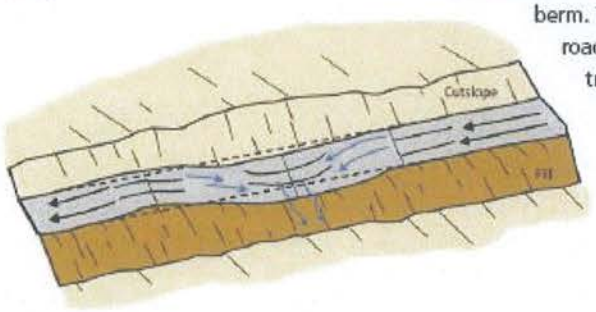
BMP: Rolling Dip Design and Placement (Types)

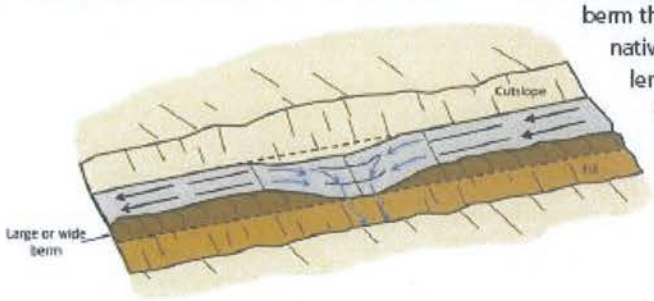
Type 1 Rolling Dip
(Standard)

Type 1 rolling dips are used where road grades are less than about 12-14% and road runoff is not confined by a large through cut or berm. The axis of the dip should be perpendicular to the road alignment and sloped at 3-4% across the road tread. Steep roads will have longer and more abrupt dip dimensions to develop reverse grade through the dip axis. The road tread and/or the dip outlet can be rocked to protect against erosion, if needed.



Type 2 Rolling Dip
(Through-cut or thick berm road reaches)

Type 2 rolling dips are constructed on roads up to 12-14% grade where there is a through cut up to 3 feet tall, or a wide or tall berm that otherwise blocks road drainage. The berm or native through cut material should be removed for the length of the dip, or at least through the axis of the dip, to the extent needed to provide for uninterrupted drainage onto the adjacent slope. The berm and slope material can be excavated and endhauled, or the material can be sidecast onto native slopes up to 45%, provided it will not enter a stream.



Type 3 Rolling Dip
(Steep road grade)

Type 3 rolling dips are utilized where road grades are steeper than about 12% and it is not feasible to develop a reverse grade that will also allow passage of the design vehicle (steep road grades require more abrupt grade reversals that some vehicles may not be able to traverse without bottoming out).

Instead of relying on the dip's grade reversal to turn runoff off the roadbed, the road is built with an exaggerated outslope of 6-8% across the dip axis. Road runoff is deflected obliquely across the dip axis and is shed off the outsloped section rather than continuing down the steep road grade.

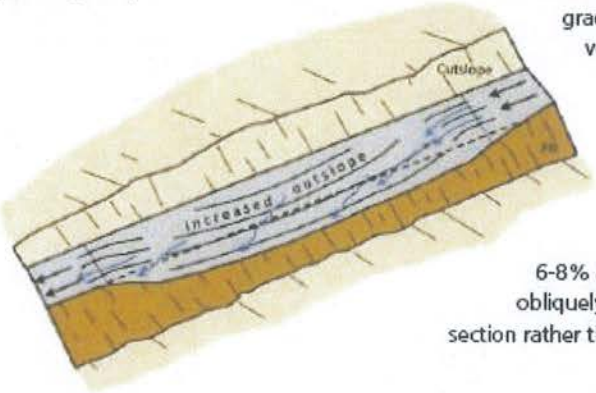


FIGURE 36. *Rolling dip types*

HANDBOOK FOR FOREST, RANCH AND RURAL ROADS

BMP: Rolling Dip Design and Placement

FIGURE 33A.
Rolling dip constructed on a rock surfaced rural road. The rolling dip represents a change-in-grade along the road alignment and acts to discharge water that has collected on, or is flowing down, the road surface. This road was recently converted from a high maintenance, insloped, ditched road to a low maintenance, outsloped road with rolling dips.

FIGURE 33B.
This side view of an outsloped road shows that the rolling dip does not have to be deep or abrupt to reverse road grade and effectively drain the road surface. This outsloped forest road has rolling dips that allow all traffic types to travel the route without changing speed.

BMP: Road Outsloping

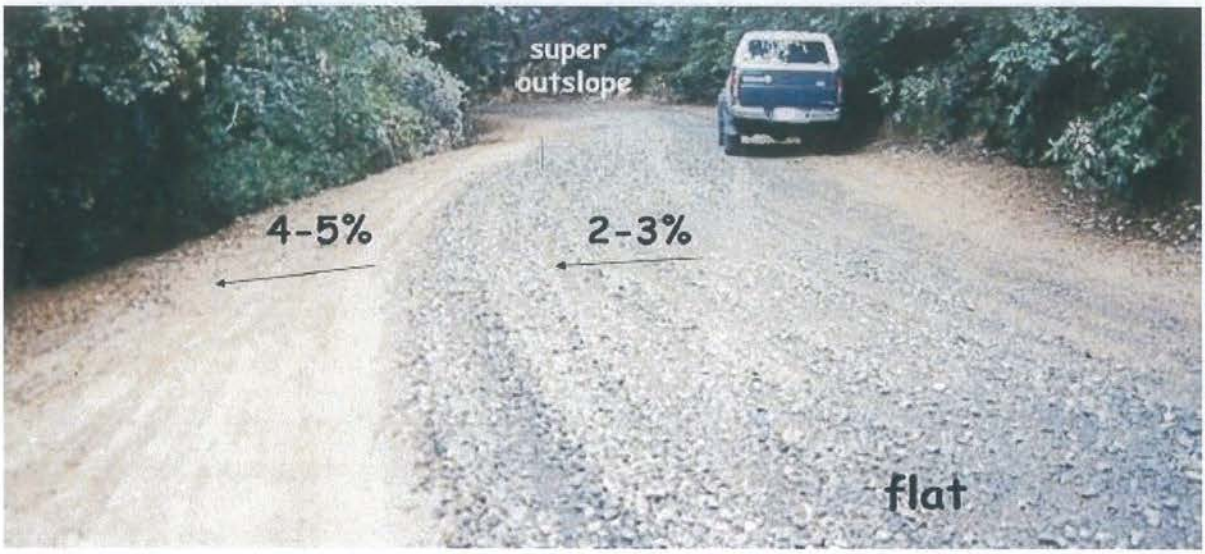


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FIGURE 29. *Road shape changes as the road travels through the landscape. For example, an outsloped road will have a steep or "banked" outslope through inside curves, a consistent outslope through straight reaches and a flat or slightly insloped shape as it goes through an outside curve. The road may have an outslope of 2-3% across the travel surface while the shoulder is more steeply outsloped to ensure runoff and sediment will leave the roadbed.*

BMP: Steep Road Drainage Structures

FIGURE 55. *Steep roads that go straight up or down a hillside are very difficult to drain. This steep, fall line road developed a through cut cross section that was drained using lead out ditches to direct runoff off the road and onto the adjacent, vegetated hillside. The road was "outsloped" to drain runoff to the right side, and the lead out ditch was built slightly steeper than the road grade, to be self-cleaning. Four lead out ditches have been constructed at 100-foot intervals to the bottom of the hillside.*

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BMP: Ditch Relief Culvert

- Install ditch relief culverts at an oblique (typically 30 degree) angle to the road so that ditch flow does not have to make a sharp angle turn to enter the pipe. On low gradient roads (<5%), where ditch flow is slow, ditch relief culverts can be installed at right angles to the road.
- Install ditch relief culverts (DRC) to outlet at, and drain to, the base of the fill
- If it cannot be installed at the base of the fill, install the DRC with a grade steeper than the inboard ditch draining to the culvert inlet, and then install a downspout on the outlet to carry the culverted flow to the base of the fillslope or energy dissipater material at outlet to prevent erosion or the outboard road fill.
- Downspouts longer than 20 feet should be secured to the hillslope for stability.
- Ditch relief culverts should not carry excessive flow such that gullying occurs below the culvert outlet or such that erosion and down-cutting of the inboard ditch is occurring.
- Do not discharge flows from ditch relief culverts onto unstable areas or highly erodible hillslopes.
- If the ditch is on an insloped or crowned road, consider reshaping road outsloping to drain the road surface. The ditch and the ditch relief culvert would then convey only spring flow from the cutbank and hillslope runoff, and not turbid runoff from the road surface.

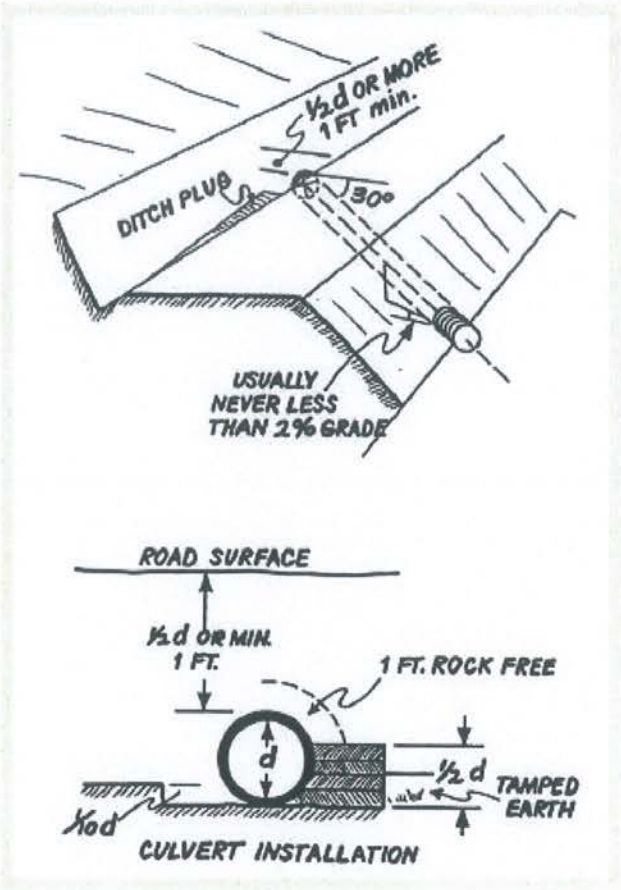

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FIGURE 48. *The elements of a properly installed ditch relief culvert. The culvert is angled at about 30 degrees to the road alignment to help capture flow and prevent culvert plugging or erosion of the inlet area. It is set at the base of the fill (ideally) or with a grade slightly steeper than the grade of the contributing ditch (but never with a grade less than 2 percent) (USDA-SCS, 1983). At a minimum, the grade of the ditch relief culvert should be sufficient to prevent sediment accumulation at the inlet or deposition within the culvert itself (it should be self-cleaning) (USDA-SCS, 1983).*

BMP: Permanent Culvert Crossing

- New culvert installations shall be sized to accommodate flows associated with a 100-year storm event.
- If the new culvert is replacing a poorly installed old culvert, the crossing may need to be abandoned to the following standard:
  - When fills are removed they shall be excavated to form a channel that is as close as feasible to natural watercourse grade and orientation, and that is wider than the natural channel.
  - Excavated banks shall be laid back to a 2:1 (50%) or natural slope.
- New culverts shall be placed at stream gradient, or have downspouts, or have energy dissipaters at outfall.
  - Align culverts with the natural stream channel orientation to ensure proper function, prevent bank erosion, and minimize debris plugging. See Figure 97 below.
  - Place culverts at the base of the fill and at the grade of the original streambed or install a downspout past the base of the fill. Downspouts should only be installed if there are no other options.
  - Culverts should be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
  - Culvert beds should be composed of rock-free soil or gravel, evenly distributed under the length of the pipe.
  - Compact the base and sidewall material before placing the pipe in its bed.
  - Lay the pipe on a well-compacted base. Poor basal compaction will cause settling or deflection in the pipe and can result in separation at a coupling or rupture in the pipe wall.
  - Backfill material should be free of rocks, limbs, or other debris that could dent or puncture the pipe or allow water to seep around the pipe.
  - Cover one end of the culvert pipe, then the other end. Once the ends are secure, cover the center.
  - Tamp and compact backfill material throughout the entire process, using water as necessary for compaction.
  - Backfill compacting will be done in 0.5 – 1.0 foot lifts until 1/3 of the diameter of the culvert has been covered.
  - Push layers of fill over the crossing to achieve the final design road grade, road fill above the culvert should be no less than one-third to one-half the culvert diameter at any point on the drivable surface.
- Critical dips shall be installed on culvert crossings to eliminate diversion potential. Refer to Figure 84 below.
- Road approaches to crossings shall be treated out to the first drainage structure (i.e. waterbar, rolling dip, or hydrologic divide) to prevent transport of sediment.
- Road surfaces and ditches shall be disconnected from streams and stream crossings to the greatest extent feasible. Ditches and road surfaces that cannot be feasible disconnected from streams or stream crossings shall be treated to reduce sediment transport to streams.
- If downspouts are used, they shall be secured to the culvert outlet and shall be secure on fill slopes.
- Culverts shall be long enough so that road fill does not extend or slough past the culvert ends.
- Inlet of culverts, and associate fill, shall be protected with appropriate measures that extend at least as high as the top of the culvert.
- Outlet of culverts shall be armored with rock if road fill sloughing into channel can occur.
- Armor inlets and outlets with rock, or mulch and seed with grass as needed (not all stream crossings need to be armored).
- Where debris loads could endanger the crossing, a debris catchment structure shall be constructed upstream of the culvert inlet.
- Bank and channel armoring may occur, when appropriate, to provide channel and bank stabilization.

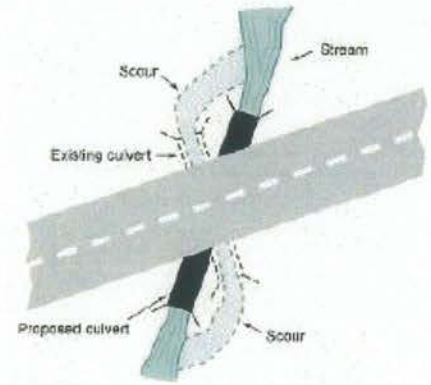

FIGURE 97. *Culvert alignment should be in relation to the stream and not the road. It is important that the stream enters and leaves the culvert in a relatively straight horizontal alignment so streamflow does not have to turn to enter the inlet or discharge into a bank as it exits. This figure shows a redesigned culvert installation that replaces the bending alignment that previously existed. Channel turns at the inlet increase plugging potential because wood going through the turn will not align with the inlet. Similarly, channel turns at the inlet and outlet are often accompanied by scour against the channel banks (Wisconsin Transportation Information Center, 2004).*

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BMP: Permanent Culvert Crossing Design (Critical Dip and Hydrologic Disconnect Placement)

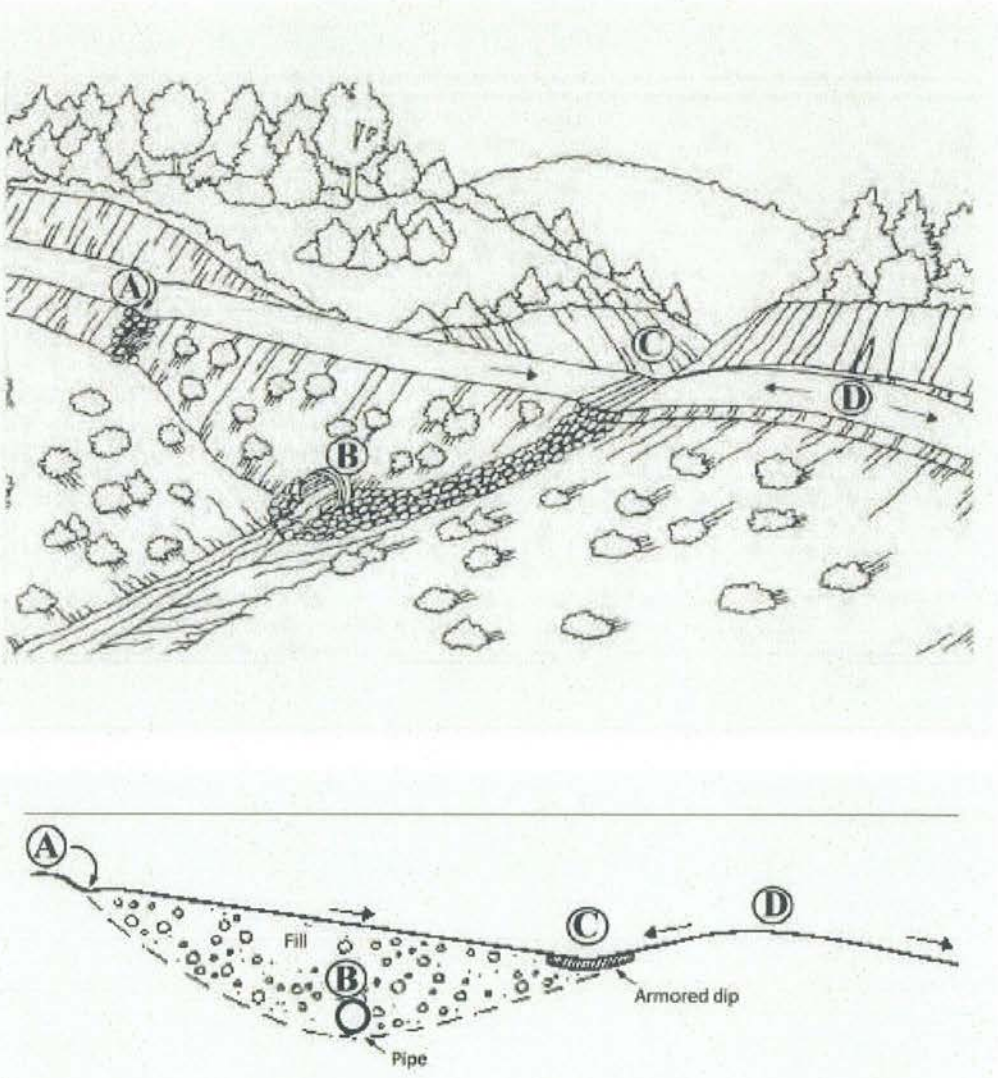

FIGURE 84. *Critical dips or dipped crossing fills should be centered near a stream crossing's down-road hingeline, not over the centerline of the crossing where overtopping could cause washout or severe erosion of the fill. If the stream crossing culvert (B) plugs, water will pond behind the fill until reaching the critical dip or low point in the crossing (C) and flowing back down into the natural stream channel. The down-road ditch must be plugged to prevent streamflow from diverting down the ditch line. For extra protection in this sketch, riprap armor has been placed at the critical dip outfall and extending downslope to the stream channel. This is only required or suggested on stream crossings where the culvert is highly likely to plug and the crossing fill overtopped. The dip at the hinge line is usually sufficient to limit erosional damage during an overtopping event. Road surface and ditch runoff is disconnected from the stream crossing by installing a rolling dip and ditch relief culvert just up-road from the crossing (A) (Keller and Sherar, 2003).*

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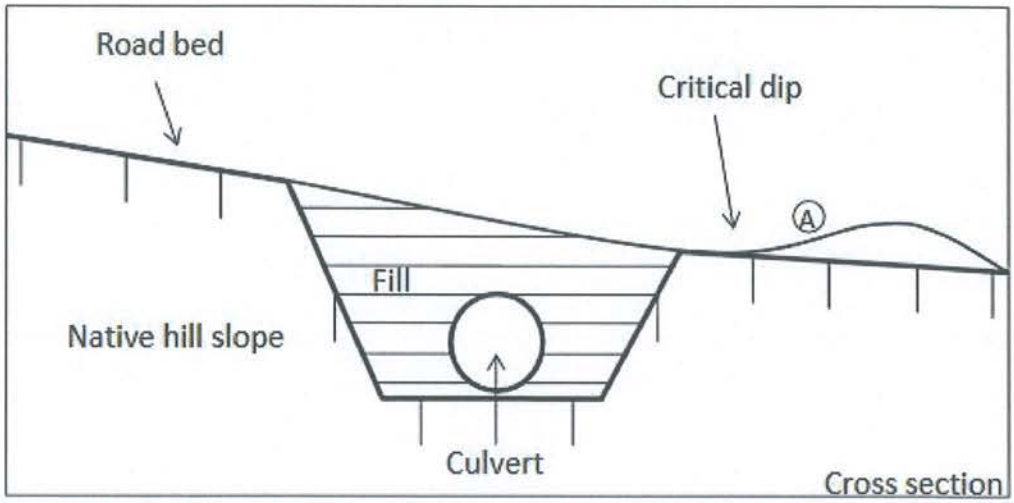
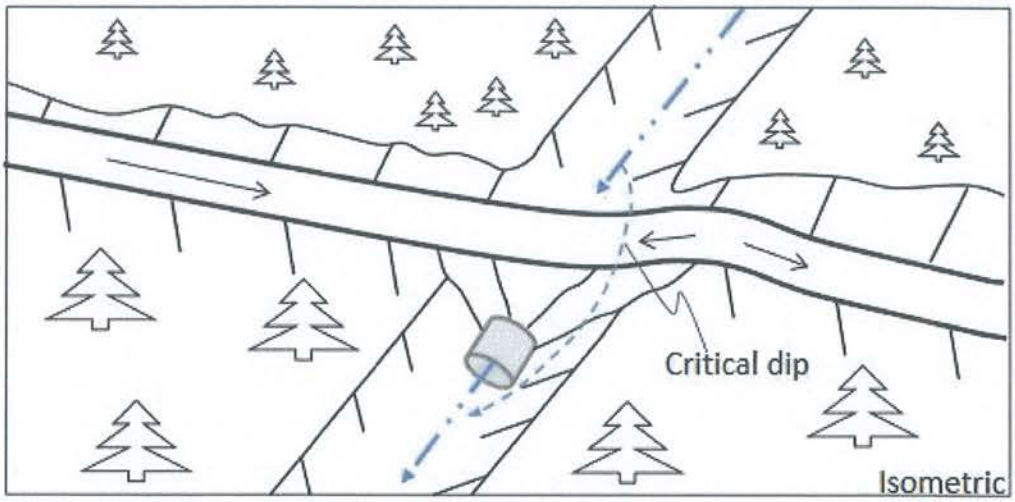
BMP: Permanent Culvert Crossing Design (Critical Dip)

Typical Critical Dip Design for Stream Crossings with Diversion Potential





Critical Dip Construction:

1. Critical dip will be constructed on the lower side of crossing.
2. Critical dip will extend from the cutbank to the outside edge of the road surface. Be sure to fill inboard ditch, if present.
3. Critical dip will have a reverse grade Ⓐ from cutbank to outside edge of road to ensure flow will not divert outside of crossing.
4. The rise in the reverse grade will be carried for about 10 to 20 feet and then return to original slope.
5. The transition from axis of bottom, through rising grade, to falling grade, will be in the road distance of at least 15 to 30 feet.
6. Critical dips are usually built perpendicular to the road surface to ensure that flow is directed back into the stream channel.

BMP: Permanent Culvert Crossing Design (Culvert Orientation)

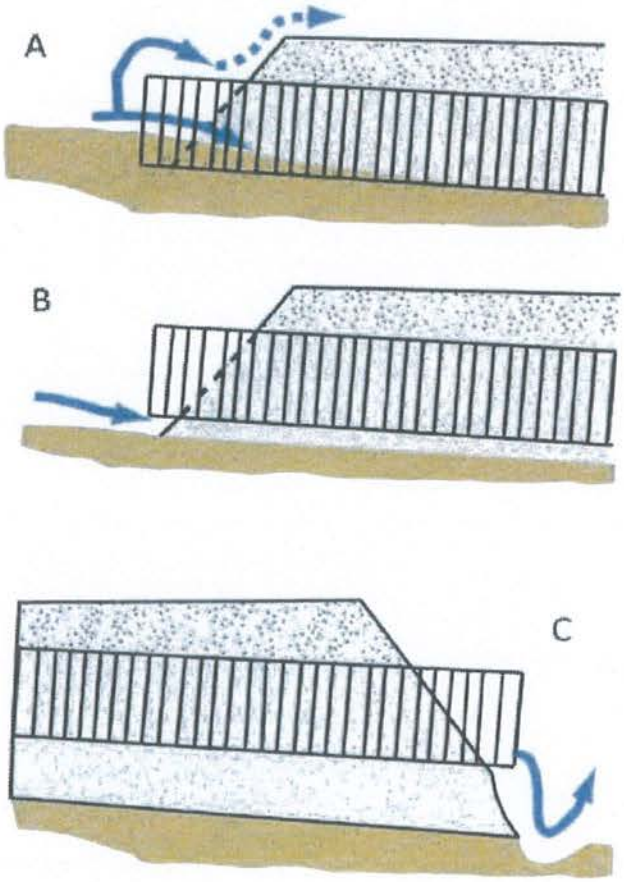
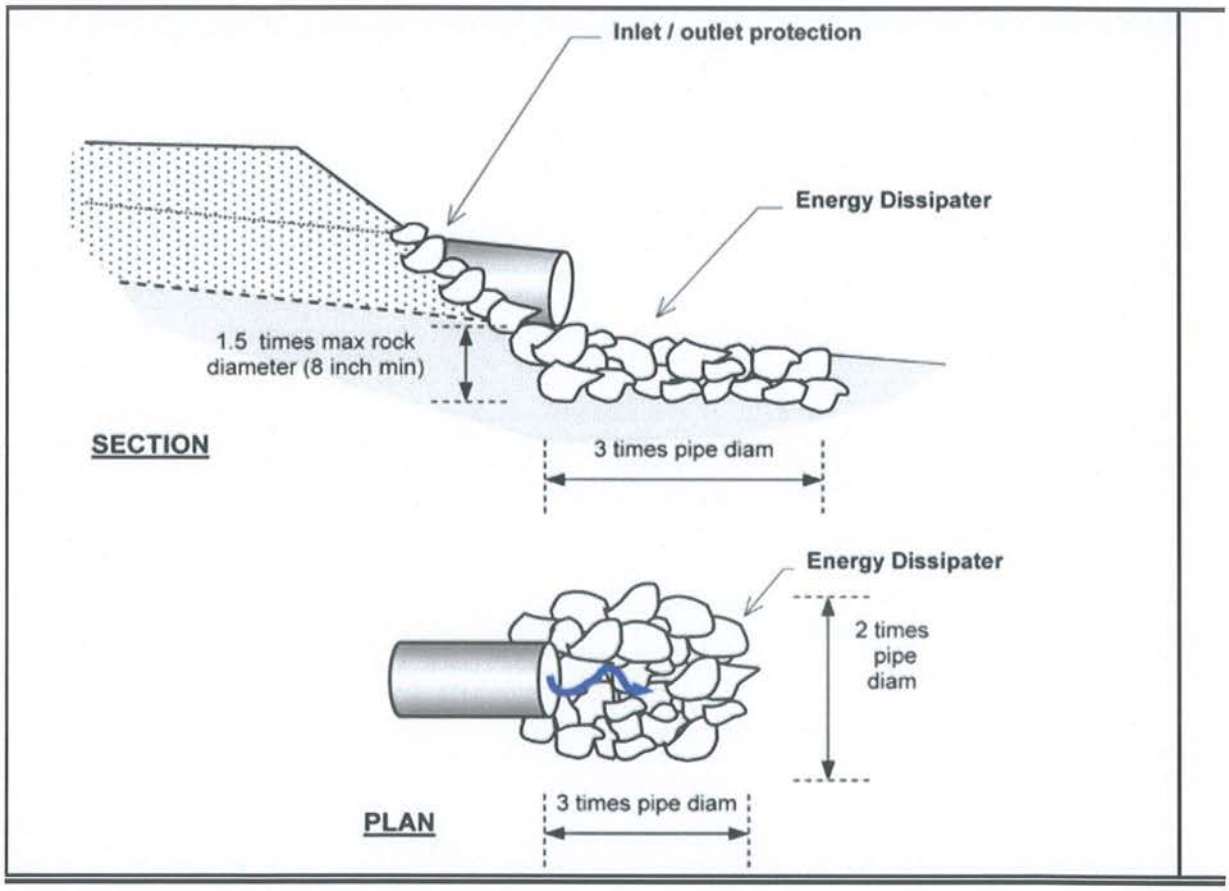
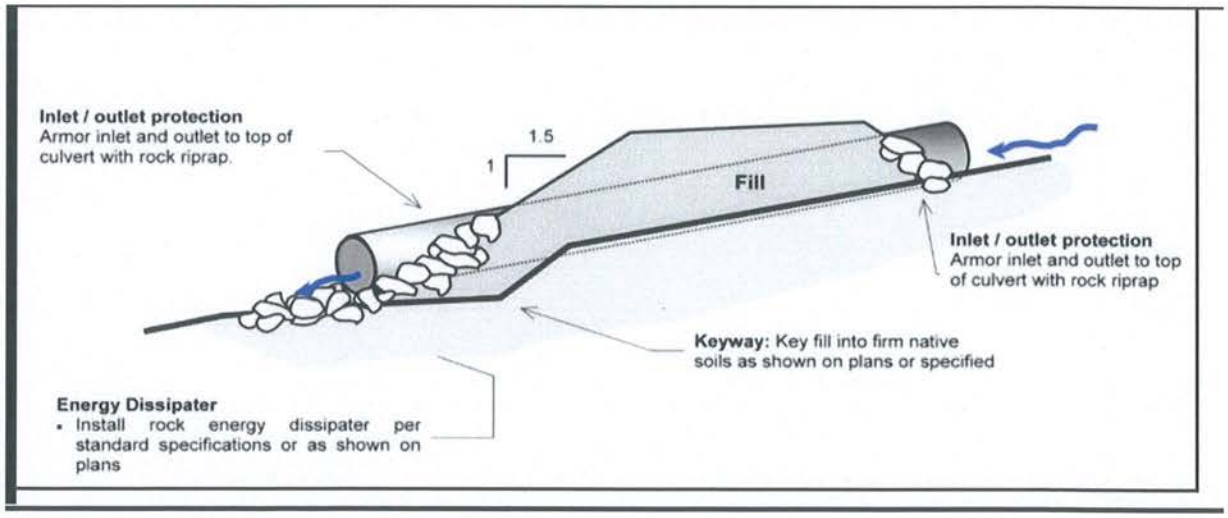


FIGURE 155. *Proper culvert installation involves correct culvert orientation, setting the pipe slightly below the bed of the original stream, and backfilling and compacting the fill as it is placed over the culvert. Installing the inlet too low in the stream (A) can lead to culvert plugging, yet if set too high (B) flow can undercut the inlet. If the culvert is placed too high in the fill (C), flow at the outfall will erode the fill. Placed correctly (D), the culvert is set slightly below the original stream grade and protected with armor at the inlet and outlet. Culverts installed in fish-bearing stream channels must be inset into the streambed sufficiently (>25% embedded) to have a natural gravel bottom throughout the culvert (Modified from: MDSL, 1991).*

BMP: Permanent Culvert Crossing Design (Inlet and Outlet Armoring)





Riprap installed to protect the inlet and outlet of a stream crossing culvert from erosion or for energy dissipation should be keyed into the natural channel bed and banks to an approximate depth of about 1.5x the maximum rock thickness. Riprap should be placed at least up to the top of the culvert at both the inlet and outlet to protect them from splash erosion and to trap any sediment eroded from the newly constructed fill slope above.

BMP: Permanent Culvert Crossing Design (Inlet and Outlet Armoring) Cont.

- Inlets of culverts and associate fills shall be protected with rock armoring that extends at least as high as the top of the culvert.
- Outlets of culverts shall be provided a rocked energy dissipater at the outfall of the culvert.
- Outlets of culverts and associate fills shall be protected with rock armoring that extends at least as high as the top of the culvert if road fill sloughing into channel can occur.
- Prior to inlet and outlet rocking, the inlet and outlets shall be prepared. Preparation will include removal of vegetation and stored materials from the inlet and outlet.
- Inlets may require construction of an inlet basin.
- Slopes at the outlet should be shaped to a 2:1 or natural slope prior to placing rock armor.
- Rock used at culvert inlets and outlets should be a matrix of various sized rocks and rip-rap that range from a 3" dia. to a 2' dia.
- The largest rocks should be places at the base of the culvert or fill. Incrementally smaller rocks shall be placed over the larger rocks at the armoring extend up the slope. Voids and spaces shall be back filed with smaller gravels and rocks.

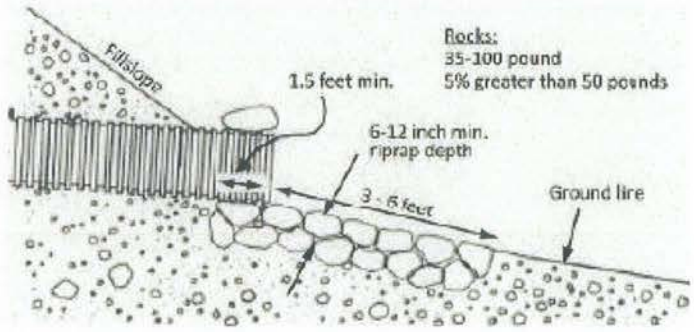


FIGURE 107A. *Riprap armor at culvert outlet (Modified from: Keller et al., 2011).*

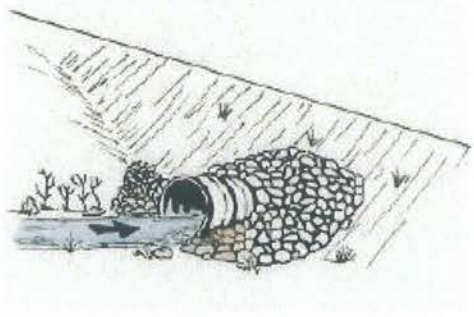


FIGURE 107B. *Riprap armor at culvert inlet (Keller and Sherar, 2003).*

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MAPS