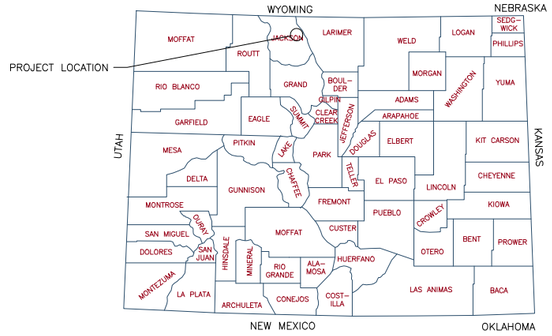
DUCKS UNLIMITED

PROJECT

NORTH SAND CREEK RIPARIAN RESTORATION LTPBR STRUCTURES REACHES 3–4

LOCATED IN SECTION(S) 6, 7 TOWNSHIP 10N, RANGE 78W, 6TH P.M., JACKSON COUNTY, CO

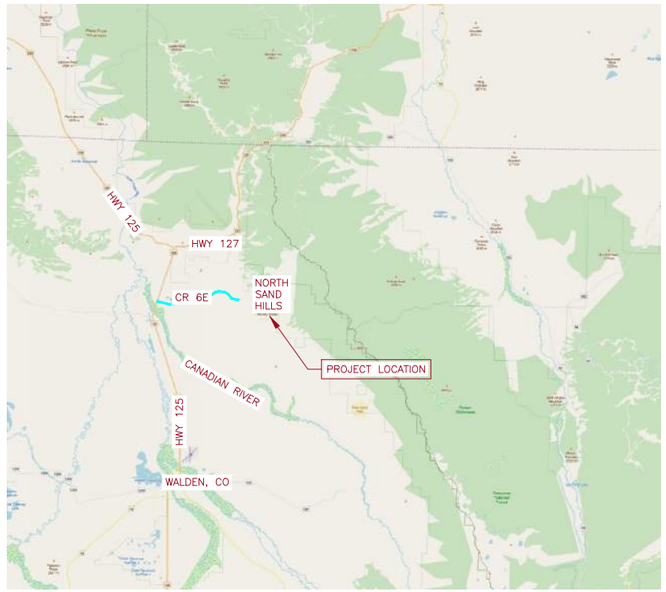


BEFORE YOU DIG

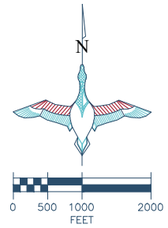
COLORADO UTILITIES NOTE: BEFORE THE START OF CONSTRUCTION, THE OWNER OF ANY UTILITIES INVOLVED MUST BE NOTIFIED. THE EXCAVATOR/CONTRACTOR IS RESPONSIBLE FOR GIVING THIS NOTICE BY CALLING "COLORADO ONE CALL" AT 811 OR 1–800–922–1987 AT LEAST 2 FULL BUSINESS DAYS PRIOR TO ANY EXCAVATION.

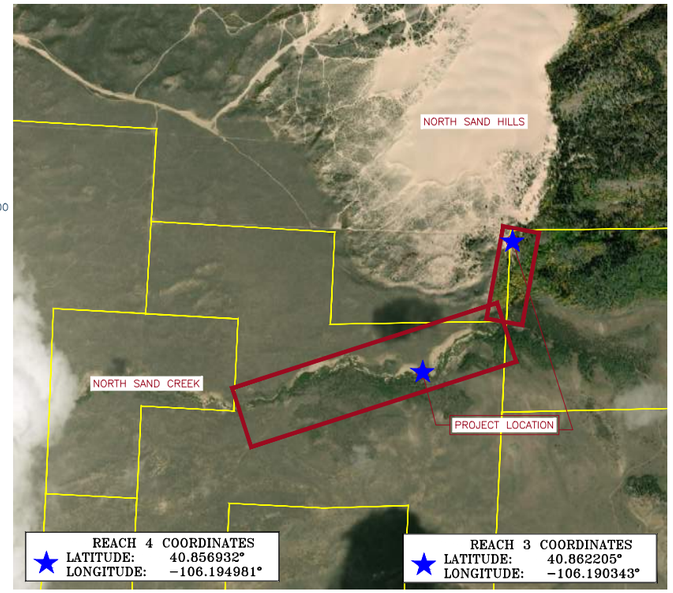
SPECIFICATIONS

101 GENERAL CONDITIONS
102 SUPPLEMENTAL CONDITIONS
201 MOBILIZATION
202 SITE PREPARATION
203 EXCAVATION
205 WATER
206 CONSTRUCTED TOPOGRAPHY
317 FENCING
401 SOIL EROSION AND POLLUTION CONTROL



VICINITY MAP
NOT TO SCALE





LOCATION MAP
SCALE: 1" = 1000'

ESTIMATED QUANTITIES

MOBILIZATION	1	L.S.
SITE PREPARATION	1	L.S.
REACH #3 (STATE LAND BOARD)		
CHANNEL–SPANNING POST–ASSISTED LOG STRUCTURE (CS PAL)	11	EA.**
BEAVER DAM ANALOG – POST–ASSISTED (BDA)	7	EA.**
REACH #4 (DUNAWAY PROPERTY)		
BEAVER DAM ANALOG – POST–ASSISTED (BDA)	21	EA.**
CHANNEL–SPANNING POST–ASSISTED LOG STRUCTURE (CS PAL)	9	EA.**

** PAYMENT WILL BE BASED ON THE PLAN QUANTITY LISTED ABOVE.

PLAN INDEX

MANAGER OF ENGINEERING SERVICES:
KEVIN WARNER, P.E.
2114 MIDPOINT DRIVE, SUITE 1
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(970) 590–1545
KWARNER@DUCKS.ORG

DU REGIONAL ENGINEER:
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DUCKS UNLIMITED
GREAT PLAINS REGION
FORT COLLINS FIELD OFFICE
2114 MIDPOINT DRIVE,
SUITE 1
FORT COLLINS, CO 80525

CERT. OF AUTHORIZATION:

DESIGNED BY: SC
DRAWN BY: TRP
SURVEYED BY:
CHECKED BY:
APPROVED BY:
APPROVED BY:

REVISION: | DATE: | BY:
1 2 3 4 5 6 7 8

PROJECT: NORTH SAND CREEK RIPARIAN RESTORATION LTPBR STRUCTURES REACHES 3–4

SHEET TITLE: VICINITY AND LOCATION MAPS

LEGAL:
SEC.:6, 7
T10N–R78W
6TH P.M.
JACKSON COUNTY, CO

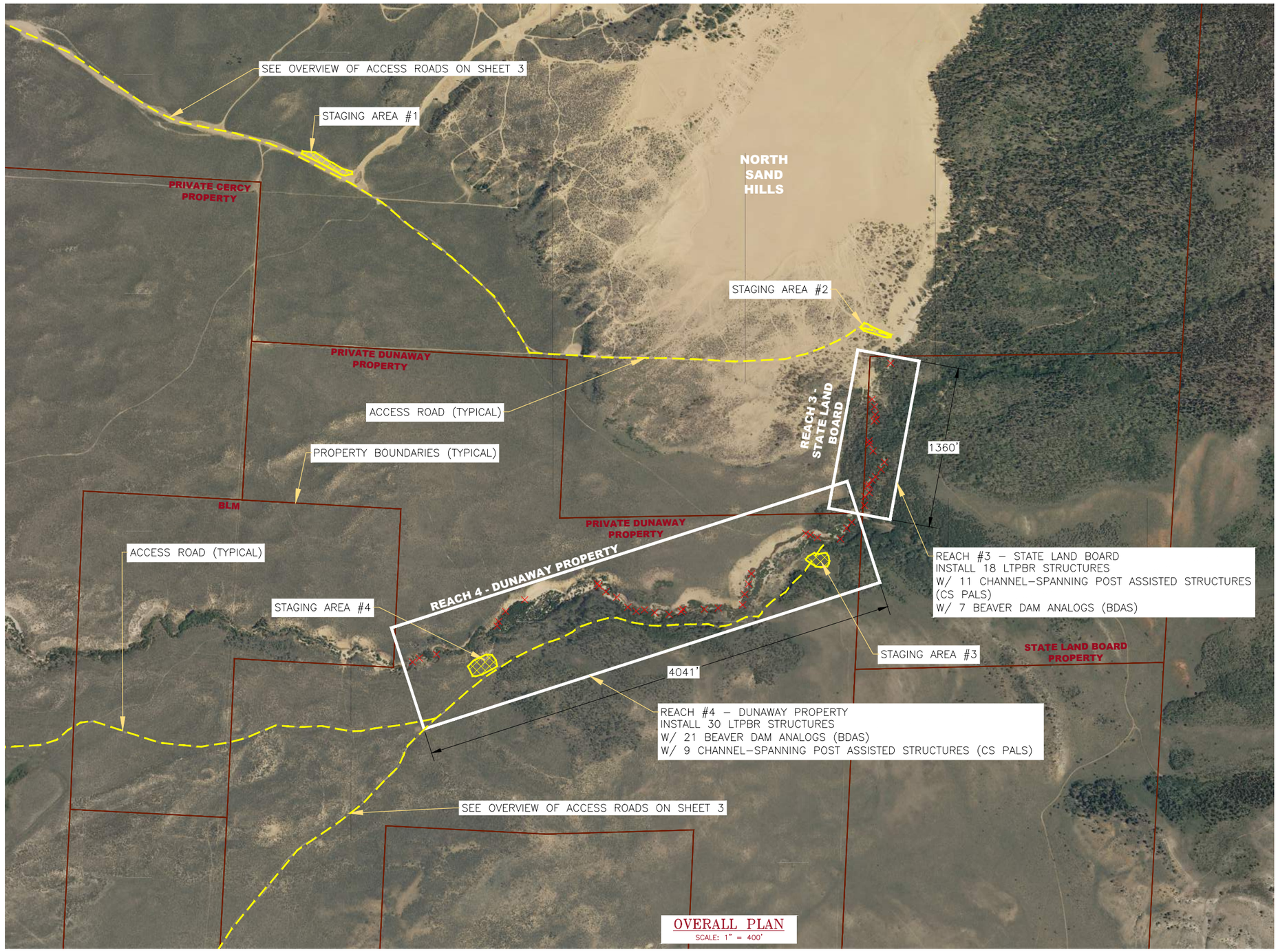
DATE: 5/6/2026

LISTED SCALES ACCURATE ON 24"X36" SHEET SIZE

DU PROJECT NUMBER: CO–360–101

SHEET NUMBER: 1 OF 11

FILE LOCATION: C:\Users\tparker\OneDrive – Ducks Unlimited Incorporated\!_Personal_Projects\(CO–360–100) North Sand Creek Restoration Collaborative\Plans and Drawings\Sheets\CO–360–100_NorthSandCreek_Reaches3–4_COVER_SHEET.dwg



OVERALL PLAN
SCALE: 1" = 400'

N

0 200 400 800
FEET

NOTES
1. CONTRACTOR IS RESPONSIBLE FOR SUPPLY & INSTALL OF POSTS FOR POST–ASSISTED STRUCTURES.
2. POSTS SHOULD BE UNTREATED WITH A MINIMUM DIAMETER OF 3–IN AND MAXIMUM DIAMETER OF 6–IN.
3. IT IS HIGHLY ENCOURAGED TO BRING A HYDRAULIC POST–POUNDER FOR THE INSTALL OF THE POSTS. A UTV OR ATV IS ALSO HIGHLY ENCOURAGED TO ACCESS THE STRUCTURE INSTALLATION AREAS.
4. IF REQUIRED, POSTS SHOULD BE CUT TO MATCH THE DESIGN HEIGHT PRESENTED IN THE TABLES ON SHEETS 3–4. GENERAL EMBEDMENT RECOMMENDATIONS IS ¼ TO ⅓ OF THE POST LENGTH. GENERALLY, 4–FT TO 5–FT POSTS SHOULD SUFFICIENT FOR THIS PROJECT.
5. GENERAL RULE OF THUMB IS A POST SHOULD BE INSTALLED EVERY 2–FT LENGTHWISE AND WIDTH–WISE WITHIN THE STRUCTURE. CONTRACTOR TO SUPPLY ENOUGH POSTS TO ACCOMPLISH THIS SPECIFICATION.
6. PROPOSED STRUCTURE LOCATIONS AND LOGS TO–BE FELLED WILL BE STAKED OR FLAGGED ACCORDINGLY.
7. CONTRACTOR SHOULD AVOID FRESH DISTURBANCE IN NATIVE VEGETATION AND KEEP DISTURBANCE TO EXISTING DISTURBED SAND AREAS.
8. ANY FENCING THAT NEEDS TO BE CUT FOR ACCESS SHOULD BE RESTORED TO EXISTING CONDITION AFTER STRUCTURE INSTALLS. THIS IS CONSIDERED INCIDENTAL TO THE "SITE PREPARATION" LINE ITEM.

ABBREVIATIONS LIST
BA PAL = BANK–ATTACHED POST–ASSISTED LOG STRUCTURE
BDA = BEAVER DAM ANALOG
BLM = BUREAU OF LAND MANAGEMENT
C.L. = CENTER LINE
CS PAL = CHANNEL–SPANNING POST–ASSISTED LOG STRUCTURE
CS FT = CHANNEL–SPANNING FELLED TREE
DIA. = DIAMETER
ELEV. = ELEVATION
EX. = EXISTING
FSL = FULL SERVICE LEVEL
INV = INVERT
LAT = LATITUDE (WGS84)
LONG = LONGITUDE (WGS84)
LTPBR = LOW–TECH PROCESS–BASED RESTORATION
WCS = WATER CONTROL STRUCTURE
WSEL = WATER LEVEL

*NOTE: NOT ALL ABBREVIATIONS IN THIS LIST APPEAR ON THIS SHEET

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CERT. OF AUTHORIZATION:

DESIGNED BY: SC
DRAWN BY: TRP
SURVEYED BY:
CHECKED BY:
APPROVED BY:
APPROVED BY:

REVISION: DATE: BY:
1 2 3 4 5 6 7 8

PROJECT: NORTH SAND CREEK RIPARIAN RESTORATION LTPBR STRUCTURES REACHES 3–4

SHEET TITLE: OVERALL PLAN

LEGAL:
SEC.:6, 7
T10N–R78W
6TH P.M.
JACKSON COUNTY, CO

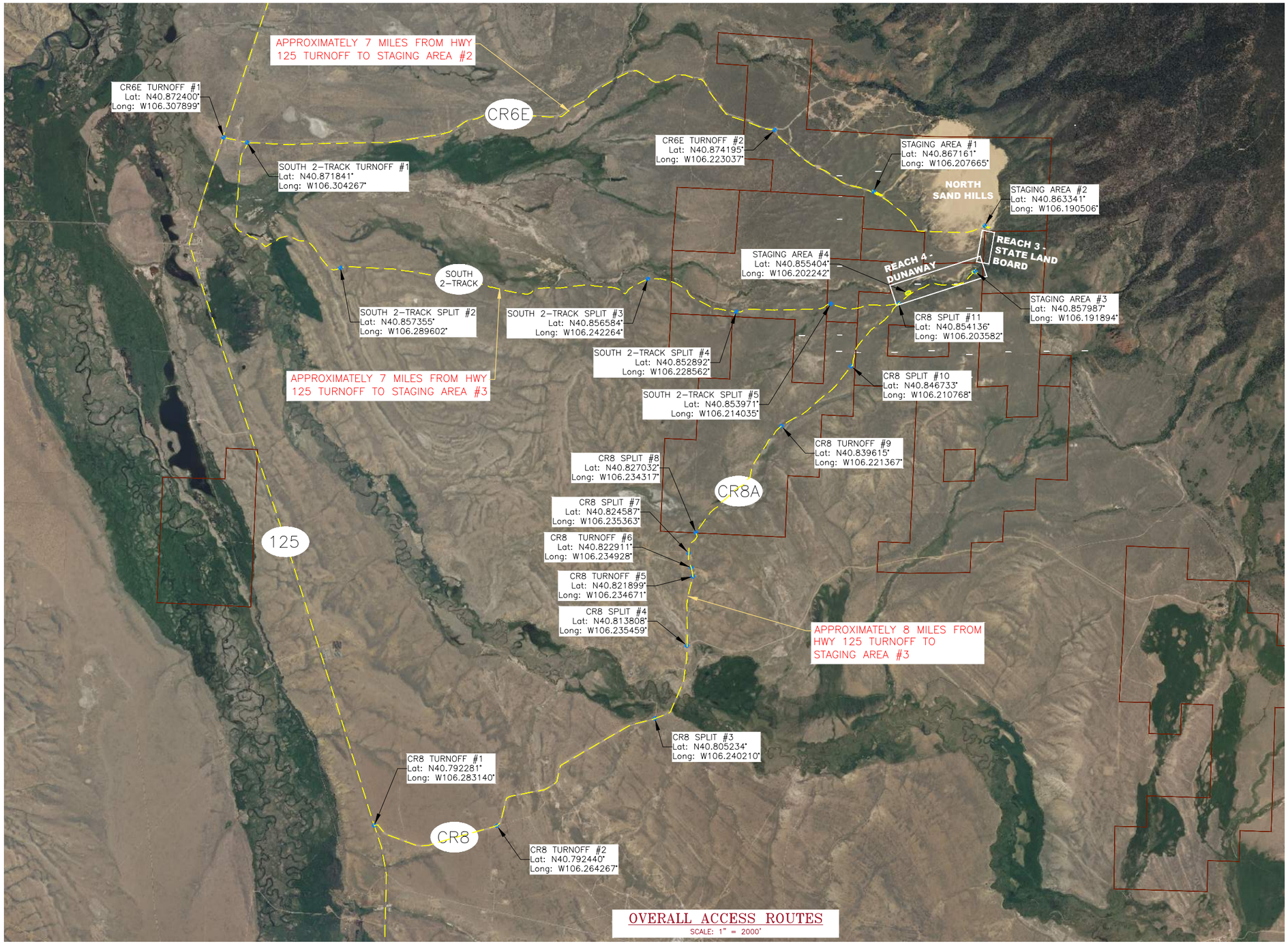
DATE: 5/6/2026

LISTED SCALES ACCURATE ON 24"X36" SHEET SIZE

DU PROJECT NUMBER: CO–360–101

SHEET NUMBER: 2 OF 11

FILE LOCATION: C:\Users\tparker\OneDrive – Ducks Unlimited Incorporated\!_Personal_Projects\(CO–360–100) North Sand Creek Restoration Collaborative\Plans and Drawings\Sheets\CO–360–100_NorthSandCreek_Reaches3–4_OVERALL_SHT2.dwg



OVERALL ACCESS ROUTES

SCALE: 1" = 2000'

N

0 1000 2000 4000
FEET

NOTES

1. MOST OF THE ACCESS ROADS REQUIRE CROSSING THROUGH PRIVATE LANDS. CONTRACTOR TO COORDINATE WITH DU CONSTRUCTION ENGINEER BEFORE USING ANY OF THE DELINEATED ACCESS ROADS. DU CONSTRUCTION ENGINEER WILL COORDINATE WITH PRIVATE LANDOWNERS.
2. LEAVE ANY GATE THE WAY YOU FOUND IT. ANY DAMAGE TO FENCING OR GATES FROM MOBILIZATION OR DAY-TO-DAY TRAFFIC TO BE RESTORED IMMEDIATELY.
3. DU CONSTRUCTION ENGINEER CAN PROVIDE GPS ROUTE FOR EACH ACCESS PATH UPON REQUEST.
4. MOST ACCESS POINTS WILL REQUIRE AN ATV OR OHV FOR ACCESS. IF LARGER EQUIPMENT IS PLANNED FOR CONSTRUCTION, THEN CONTRACTOR TO COORDINATE ACCESS PLAN WITH DU ENGINEER TO MINIMIZE NATIVE VEGETATION DISTURBANCE.

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FILE LOCATION: C:\Users\tparker\OneDrive - Ducks Unlimited Incorporated\!_Personal_Projects\(CO-360-100) North Sand Creek Restoration Collaborative\Plans and Drawings\Sheets\CO-360-100_NorthSandCreek_Reaches3-4_OVERALL_SHT2.dwg

DUCKS UNLIMITED
GREAT PLAINS REGION
FORT COLLINS FIELD OFFICE
2114 MIDPOINT DRIVE,
SUITE 1
FORT COLLINS, CO 80525

CERT. OF AUTHORIZATION:

DESIGNED BY: SC
DRAWN BY: TRP
SURVEYED BY:
CHECKED BY:
APPROVED BY:
APPROVED BY:

REVISION:	DATE:	BY:
1		
2		
3		
4		
5		
6		
7		
8		

PROJECT: NORTH SAND CREEK RIPARIAN RESTORATION LTPBR STRUCTURES REACHES 3-4

SHEET TITLE: ACCESS PLAN

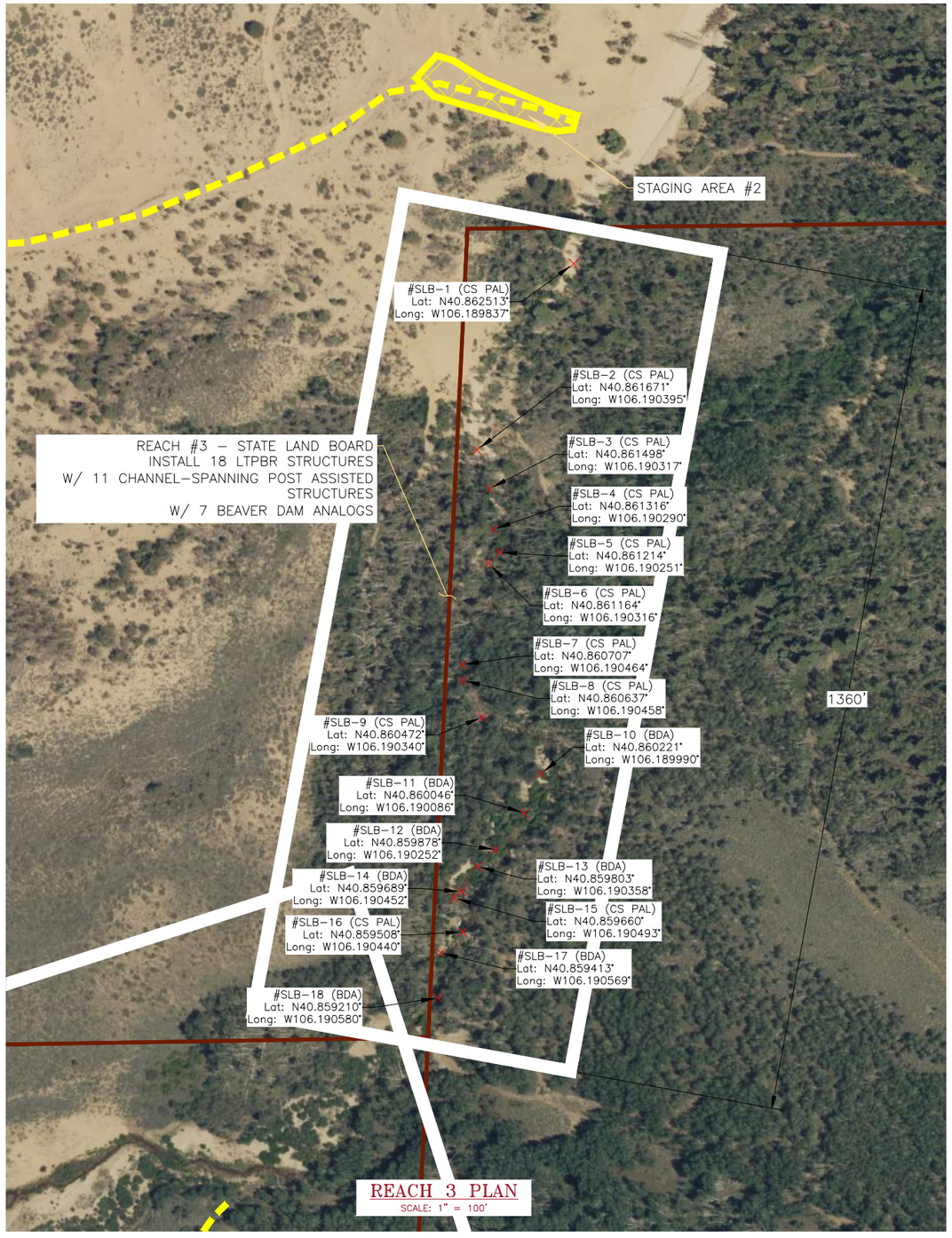
LEGAL:
SEC.:6, 7
T10N-R78W
6TH P.M.
JACKSON COUNTY, CO

DATE: 5/6/2026

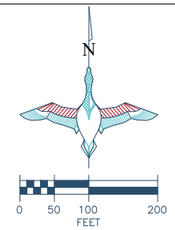
LISTED SCALES ACCURATE ON 24"X36" SHEET SIZE

DU PROJECT NUMBER: CO-360-101

SHEET NUMBER: 3 OF 11



REACH 3 PLAN
SCALE: 1" = 100'



EXAMPLE PHOTO OF EXISTING CONDITIONS IN REACH 3

NOTES:
- SEE TYPICAL DETAILS AND CONSTRUCTION GUIDANCE ON SHEETS 5–12
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- CONTRACTORS SHOULD ALSO REFERENCE THE "NORTH SAND CREEK AREA RIPARIAN RESTORATION – SITE ASSESSMENT AND PRIORITY RESTORATION ACTIONS" REPORT BY BIO–LOGIC FOR BACKGROUND ON THE PROJECT INTENT AND GOALS.

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REACH 3 (STATE LAND BOARD) - STRUCTURES SPECIFICATIONS

STRUCTURE	STRUCTURE TYPE	LENGTH (FT)	WIDTH (FT)	HEIGHT (FT)	ESTIMATED # OF POSTS NEEDED	COMMENT
#SLB-1	CS PAL	8	20	1.5	27	Debris Jam, Sand, Priority
#SLB-2	CS PAL	6	18	1.5	18	Debris Jam, Sand
#SLB-3	CS PAL	8	28	1.5	38	Debris Jam, Sand
#SLB-4	CS PAL	8	10	1.5	14	Debris Jam, VL Spreader Willow
#SLB-5	CS PAL	8	26	2	35	Debris Jam, Sand, Priority
#SLB-6	CS PAL	6	8	1.5	8	Debris Jam, Sand, Water Below
#SLB-7	CS PAL	8	16	1.5	22	Debris Jam, Grade Control Willow
#SLB-8	CS PAL	6	12	1.5	12	Debris Jam, Grade Control Rock
#SLB-9	CS PAL	8	16	2	22	Debris Jam, Grade Control Alder
#SLB-10	BDA	6	8	1.5	8	BDA, Highest Valley Right
#SLB-11	BDA	6	14	1.5	14	BDA, Alder, Willow
#SLB-12	BDA	6	12	1.5	12	BDA
#SLB-13	BDA	8	12	1.5	16	BDA
#SLB-14	BDA	6	16	1	16	BDA, Existing
#SLB-15	CS PAL	6	4	1	4	Debris Jam, Existing
#SLB-16	CS PAL	6	15	1.5	15	Debris Jam, Existing
#SLB-17	BDA	8	20	1.5	27	BDA, Existing Jam
#SLB-18	BDA	6	14	1.5	14	BDA
				TOTAL	322	

ABBREVIATIONS LIST
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SUITE 1
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CERT. OF AUTHORIZATION:

DESIGNED BY: SC
DRAWN BY:
SURVEYED BY: TRP
CHECKED BY:
APPROVED BY:
APPROVED BY:

REVISION: 1 2 3 4 5 6 7 8
DATE:
BY:

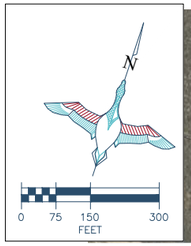
PROJECT: NORTH SAND CREEK RIPARIAN RESTORATION LTPBR STRUCTURES REACHES 3–4

SHEET TITLE: REACH 3 OVERVIEW

LEGAL:
SEC.:6, 7
T10N–R78W
6TH P.M.
JACKSON COUNTY, CO

DATE: 5/6/2026
LISTED SCALES ACCURATE ON 24"X36" SHEET SIZE
DU PROJECT NUMBER: CO–360–101
SHEET NUMBER: 4 OF 11

FILE LOCATION: C:\Users\tparker\OneDrive – Ducks Unlimited Incorporated\!_Personal_Projects\(CO–360–100) North Sand Creek Restoration Collaborative\Plans and Drawings\Sheets\CO–360–100_NorthSandCreek_Reaches3–4_SHEETS.dwg



NOTES:

- SEE TYPICAL DETAILS AND CONSTRUCTION GUIDANCE ON SHEETS 5–12
- CONTRACTORS SHOULD REFERENCE DR. WHEATON'S "LOW–TECH PROCESS–BASED RESTORATION OF RIVERSCAPES: DESIGN MANUAL" FOR MORE INFORMATION ABOUT STRUCTURE INSTALLATION. THE TYPICAL DETAILS WERE PULLED FROM THIS DOCUMENT.
- CONTRACTORS SHOULD ALSO REFERENCE THE "NORTH SAND CREEK AREA RIPARIAN RESTORATION – SITE ASSESSMENT AND PRIORITY RESTORATION ACTIONS" REPORT BY BIO–LOGIC FOR BACKGROUND ON THE PROJECT INTENT AND GOALS.

REACH 4 PLAN

SCALE: 1" = 150'

EXAMPLE PHOTO OF EXISTING CONDITIONS IN REACH 4

NOTES

1. CONTRACTOR IS RESPONSIBLE FOR SUPPLY & INSTALL OF POSTS FOR POST–ASSISTED STRUCTURES.
2. POSTS SHOULD BE UNTREATED WITH A MINIMUM DIAMETER OF 3–IN AND MAXIMUM DIAMETER OF 6–IN.
3. IT IS HIGHLY ENCOURAGED TO BRING A HYDRAULIC POST–POUNDER FOR THE INSTALL OF THE POSTS. A UTV OR ATV IS ALSO HIGHLY ENCOURAGED TO ACCESS THE STRUCTURE INSTALLATION AREAS.
4. IF REQUIRED, POSTS SHOULD BE CUT TO MATCH THE DESIGN HEIGHT PRESENTED IN THE TABLES ON SHEETS 3–4. GENERAL EMBEDMENT RECOMMENDATIONS IS ⅓ OF THE POST LENGTH. 4–FT TO 5–FT POSTS SHOULD SUFFICIENT FOR THIS PROJECT.
5. GENERAL RULE OF THUMB IS A POST SHOULD BE INSTALLED EVERY 2–FT LENGTHWISE AND WIDTH–WISE WITHIN THE STRUCTURE. CONTRACTOR TO SUPPLY ENOUGH POSTS TO ACCOMPLISH THIS SPECIFICATION. SEE ESTIMATES FOR NUMBER OF POSTS BELOW.
6. PROPOSED STRUCTURE LOCATIONS AND LOGS TO–BE FELLED WILL BE STAKED OR FLAGGED ACCORDINGLY.
7. CONTRACTOR SHOULD AVOID FRESH DISTURBANCE IN NATIVE VEGETATION AND KEEP DISTURBANCE TO EXISTING DISTURBED SAND AREAS.
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REACH 4 (DUNAWAY PROPERTY) - STRUCTURES SPECIFICATIONS						
STRUCTURE	STRUCTURE TYPE	LENGTH (FT)	WIDTH (FT)	HEIGHT (FT)	ESTIMATED # OF POSTS NEEDED	COMMENT
#DP-1	BDA	6	14	1.5	14	BDA
#DP-2	BDA	8	16	2	22	BDA
#DP-3	BDA	8	18	2.5	24	BDA
#DP-4	BDA	6	14	1.5	14	BDA
#DP-5	BDA	10	25	2.5	42	BDA Valley Left Reconnect. Priority
#DP-6	BDA	6	14	2	14	BDA Support Structures Above
#DP-7	BDA	6	16	1.5	16	BDA
#DP-8	BDA	6	14	1.5	14	BDA
#DP-9	BDA	8	16	2.5	22	BDA
#DP-10	BDA	6	16	2	16	BDA
#DP-11	BDA	8	12	1.5	16	BDA
#DP-12	BDA	8	14	1.5	19	BDA
#DP-13	CS PAL	6	14	1.5	14	Debris Jam, Grade Control, Sand Monitoring Pt.
#DP-14	CS PAL	8	8	1.5	11	Debris Jam, Grade Control
#DP-15	BDA	10	16	2.5	27	BDA

REACH 4 (DUNAWAY PROPERTY) - STRUCTURES SPECIFICATIONS						
STRUCTURE	STRUCTURE TYPE	LENGTH (FT)	WIDTH (FT)	HEIGHT (FT)	ESTIMATED # OF POSTS NEEDED	COMMENT
#DP-16	BDA	10	16	2	27	BDA
#DP-17	BDA	8	16	2	22	BDA
#DP-18	BDA	8	14	2	19	BDA
#DP-19	CS PAL	8	16	1.5	22	Debris Jam, Valley Left Spreader
#DP-20	CS PAL	8	14	2	19	Debris Jam, Sand
#DP-21	CS PAL	8	14	1.5	19	Debris Jam
#DP-22	BDA	8	10	2	14	BDA Splitter
#DP-23	BDA	8	14	2	19	BDA
#DP-24	CS PAL	6	16	1.5	16	Debris Jam, Sand, Off Channel
#DP-25	CS PAL	6	12	1.5	12	Debris Jam, Sand Sedge Below
#DP-26	BDA	8	14	1.5	19	BDA
#DP-27	BDA	6	14	1.5	14	BDA
#DP-28	BDA	8	14	2	19	BDA
#DP-29	CS PAL	8	14	1.5	19	Debris Jam, Grade Control
#DP-30	CS PAL	8	14	2	19	Debris Jam, Grade Control
				TOTAL	564	

ABBREVIATIONS LIST

BA PAL = BANK–ATTACHED POST–ASSISTED LOG STRUCTURE
BDA = BEAVER DAM ANALOG
BLM = BUREAU OF LAND MANAGEMENT
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WSEL = WATER LEVEL

*NOTE: NOT ALL ABBREVIATIONS IN THIS LIST APPEAR ON THIS SHEET

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PROJECT: NORTH SAND CREEK RIPARIAN RESTORATION LTPBR STRUCTURES REACHES 3–4

SHEET TITLE: REACH 4 OVERVIEW

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SEC.:6, 7
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SHEET NUMBER: 5 OF 11

APPENDIX D: TYPICAL SCHEMATICS AND GENERAL SUGGESTIONS FOR PLACEMENT AND CONSTRUCTION OF PALS

We provide some basic building steps (i.e., recipes) and schematics of PALS and BDAs. We wish to stress that these recipes are not meant to describe the only way to build these structures, and the schematics are not meant as exact depictions of how these structures should be constructed. As noted in low-tech Restoration Principle 5 "it's okay to be messy" (Chapter 2: Wheaton et al., 2019), each structure type should be built in a variety of shapes and sizes depending on the site conditions, materials available, and goals of the project. We provide the recipes and schematics as a rough guide for practitioners, an "entry point" into low-tech restoration, and for permitting agencies to understand the general building approach. All schematics are licensed with a Creative Commons attribution license so practitioners can use or modify them in their own designs, reports and permit applications with appropriate citation. See Chapter 6 for general permitting, construction logistics, and safety concerns (Bennett et al., 2019a).

General Post-Assisted Log Structure (PALS) Building Recipe

Ingredients:

- branches, limbs, small logs, brushy fill generally < 6-15' long and 6-16" diameter (i.e., can be carried by 1-3 people and constructed by crew of 2-4) – (see Chapter 6: Bennett et al., 2019a)
- untreated wooden posts 6 - 8' long 2-4" diameter; can sometimes be built on site with small diameter trees and/or branches, but may not be practical for building hundreds of structures (see Chapter 6: Bennett et al., 2019a)

Instructions:

- Decide location of PALS, configuration (e.g., orientation and type of PALS) as part of the design (see Chapter 5: Shahverdian et al., 2019b) of a complex of structures (multiple structures working together)
- Position larger logs on the base of the structure to make the general shape of structure
  - Limb branches from one side of the logs so that much of the log comes in contact with the bed to increase interaction between the flow and the structure, even at low flows
- Pin large pieces in place with posts; drive posts at angles and downstream to help hold wood in place at high flows
- Add more logs, and pack and wedge smaller material to fill spaces in the structure
- Build up the structure to desired crest elevation, but crest elevation need not be uniform

Options and Considerations:

- Build PALS with irregular shapes and branches and small debris sticking out in multiple directions (i.e., make a mess)
- For PALS where flow over the top is anticipated, consider constructing a mattress of woody material on downstream side to dissipate pour over flow energy over-top of structure. Alternatively, if the intention is to encourage formation of a plunge pool, maybe build mattress incompletely, or not at all
- When building bank-attached and channel-spanning PALS, extend the structures onto the floodplain by wedging structure material into existing vegetation, trunks, roots or boulders on the floodplain
- Build bank-attached PALS with a broader base (streamwise) where the structure attaches to the bank, to better shunt flows to the opposite bank
- Locate bank-attached PALS across from hard features like boulders or roots to force a scour pool
- Build a broad base (streamwise) for channel-spanning structures relative to channel width so that the structure is not narrow and "wall like". Use multiple lines of offset posts to build it wide
- Build mid-channel PALS with large and wide logs perpendicular to the flow on the upstream end of the structure to act like a natural root wad
- In general, the larger the structure relative to the channel width (i.e., constriction width), the larger effect it will have on hydraulics, and subsequently geomorphic change during high flows

NOTES:

- USE DR. WHEATON'S "LOW-TECH PROCESS-BASED RESTORATION OF RIVERSCAPES: DESIGN MANUAL" FOR MORE INFORMATION ABOUT STRUCTURE INSTALLATION

POST-ASSISTED LOG STRUCTURES (PALS):

- STRUCTURES SHOULD MIMIC THE FORM OF WOOD ACCUMULATION AND DIRECTLY FORCE THE PROCESSES ASSOCIATED WITH WOODY DEBRIS ACCUMULATIONS.
- IN RESPONSE TO FLOODS, PALS CAN:
  - GROW BY ACTING AS PLATFORMS/OBSTRUCTIONS FOR MORE WOOD TO ACCUMULATE ON,
  - PROMOTE DIRECT RECRUITMENT OF WOODY DEBRIS BY THE HYDRAULICS THEY FORCE FROM OTHER SURFACES
  - FORCE CREATE OF SURFACES (BARS AND FLOODPLAINS) THAT RECRUIT MORE WOODY VEGETATION ESTABLISHMENT, AND
  - THE MATERIAL IN PALS CAN BE MOBILIZED AND ACCUMULATE INTO THEIR OWN NATURAL WOODY ACCUMULATIONS DOWNSTREAM.

Figure 5 - PALS can be built in a range of shapes, sizes and in different channel locations. (A) bank-attached, (B) mid-channel, (C) channel-spanning, (D) channel-spanning, (E) mid-channel, (F) channel-spanning, (G) bank-attached, and (H) channel-spanning.

NOTES:

- WOOD SHOULD GENERALLY BE HARVESTED LOCALLY. WOODY DEBRIS STRUCTURES CAN BE CONSTRUCTED FROM A VARIETY OF MATERIALS, AND THIS SITE PROVIDES MULTIPLE SOURCES OF CONIFER, WILLOW, ASPEN, AND EXTENSIVE GROUND JUNIPER THAT IS SUITABLE FOR CONSTRUCTION.
- CHANNEL-SPANNING STRUCTURES SHOULD INCORPORATE A VARIETY OF MATERIAL SIZES WITH LARGE WOODY DEBRIS FORMING THE BASE STRUCTURE AND USING AMPLE SMALLER MATERIAL AND FINES TO CLOG PORE SPACE IN THE STRUCTURE.
- UNTREATED WOODEN POSTS WOULD BE USED FOR PINNING IN AND SECURING THE WOOD STRUCTURES, AND IT IS RECOMMENDED THAT THESE MATERIALS ARE IMPORTED.

ABBREVIATIONS LIST
BA PAL = BANK-ATTACHED POST-ASSISTED LOG STRUCTURE
BDA = BEAVER DAM ANALOG
BLM = BUREAU OF LAND MANAGEMENT
C.L. = CENTER LINE
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PROJECT: NORTH SAND CREEK RIPARIAN RESTORATION LTPBR STRUCTURES REACHES 3-4

SHEET TITLE: TYPICAL DETAILS - PALS

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Channel Spanning PALS

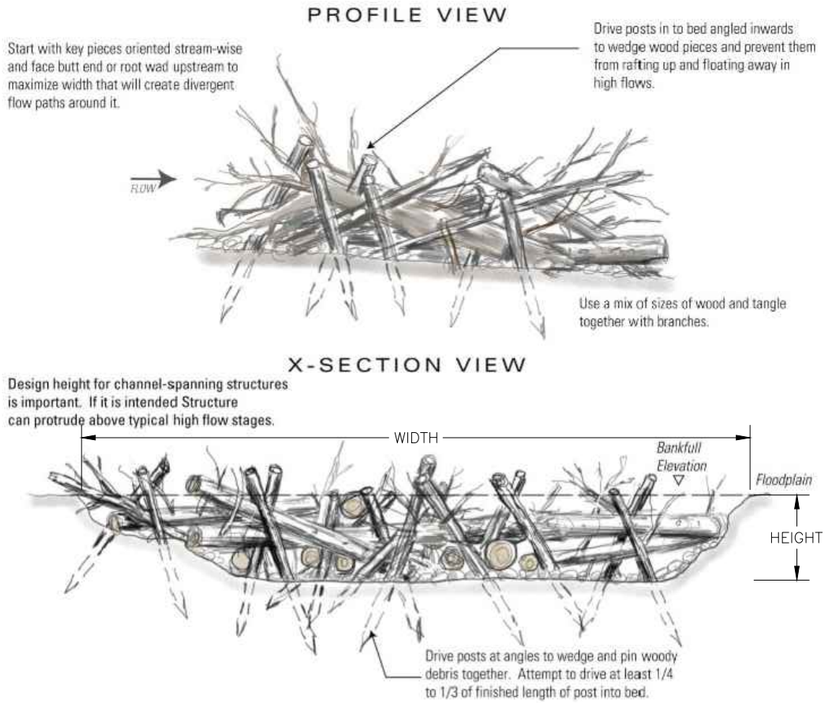

Figure 26 - Typical schematics of a channel-spanning PALS.

NOTES:

- USE DR. WHEATON'S "LOW-TECH PROCESS-BASED RESTORATION OF RIVERSCAPES: DESIGN MANUAL" FOR MORE INFORMATION ABOUT STRUCTURE INSTALLATION

Variations and Constructions Tips for PALS

There are numerous ways to build PALS, and practitioners should experiment with different substitutions and techniques. In Figure 27 the idea of substituting different types of materials is illustrated. One can build smaller PALS to start, and then make them bigger once the key pieces are pinned in. We have found that installing posts at angles is far more effective at pinning material in place (Figure 28). Finally, posts don't always drive into the bed. Posts will drive surprisingly well into cobble and gravel, but bedrock, clay hardpan, and some beds will not always work. In such situations, it can be helpful to make larger and more complicated pieces by lashing material together, and securing it or wedging it against existing features. We DO NOT recommend cabling, but biodegradable rope is an option. We do not like cabling as it is both unnecessary and leaves artificial material in the system for too long. By contrast, biodegradable materials can provide temporary stability while the structure is mimicking a wood-accumulation, gives it a chance to act as Velcro for promoting more wood accumulation, but if it washes out, it will just be a source of recruited wood to accumulate in other natural jams and PALS. Figure 29 shows one technique for lashing material together using triangle frames. This can also be helpful for combining smaller pieces into something that mimics bigger key pieces.

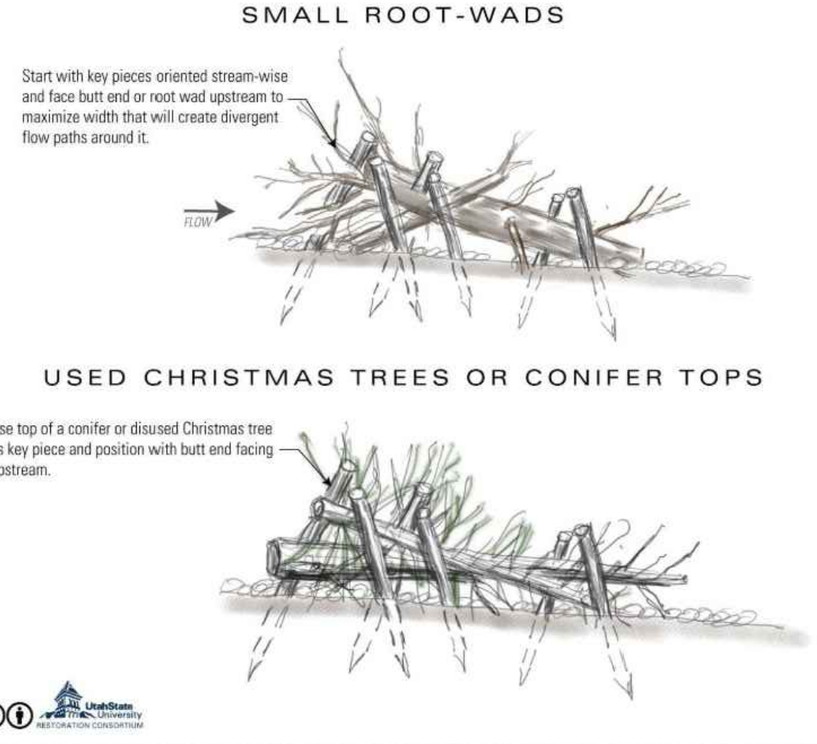

Figure 27 – Ideas for material substitutions with small root-wads and discarded/recycled Christmas trees or tops off of conifers. Smaller PALS like these can also be helpful to start with in streams and rivers with higher flow, to build something small and get it anchored, and then start piling on more material and pining it as necessary to produce something like found in the schematics.

NOTES:

- WOOD SHOULD GENERALLY BE HARVESTED LOCALLY. WOODY DEBRIS STRUCTURES CAN BE CONSTRUCTED FROM A VARIETY OF MATERIALS, AND THIS SITE PROVIDES MULTIPLE SOURCES OF CONIFER, WILLOW, ASPEN, AND EXTENSIVE GROUND JUNIPER THAT IS SUITABLE FOR CONSTRUCTION.
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PROJECT: NORTH SAND CREEK RIPARIAN RESTORATION LTPBR STRUCTURES REACHES 3-4

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APPENDIX E: TYPICAL SCHEMATICS AND GENERAL SUGGESTIONS FOR PLACEMENT AND CONSTRUCTION OF BDAS

Typical Schematic or Design Details for BDAs

In this section, we provide the sorts of schematics that can form part of a low-tech design package (see Chapter 5: Shahverdian et al., 2019b) and act as typical construction details. Many substitutions and creative adaptations to these typical details can be made to promote the processes defined in the design objectives. Do not be afraid to experiment, so long as you are following the guiding principles (see Chapter 2: Bennett et al., 2019a).

Postless BDA

Our preferred design for BDAs is very similar to how beaver build dams, without posts.

General Postless BDA Recipe

Ingredients:

- Woody fill material (preferably locally-sourced) branches, limbs, small logs, brushy fill
- Finer fill material: both organic (e.g., turf mats, roots, leaves, conifer needles, grass, etc.) and inorganic (e.g., fine bed sediment, silt, clay, soil, gravel)
- Optional if available on site: key pieces: logs, cobbles or small boulders

Tools Needed:

- Personal protective equipment (PPE) (see Chapter 6: Bennett et al., 2019a); Optionally: dry suit or waders
- Cutting tools: loppers minimally; Optionally: chainsaw, hand saw(s), and pruning shears – for sourcing, trimming and cutting to size woody fill material
- Digging tools: Shovel(s) minimally; Optionally: pick-axe and/or digging bars – for sourcing finer fill material
- 5 Gallon Buckets - for filling and moving finer fill material from source areas to BDA
- Optionally:
    - Cam straps are sometimes helpful to bundle together branches for easier hauling from source or staging areas to BDA.

Instructions:

1. Decide location of BDA dam crest orientation, configuration (e.g., straight or convex downstream), and crest elevation (use landscape flags if necessary). Position yourself with your eye-level at the proposed crest elevation of the dam (make sure it is < 5' in height). Look upstream to find where the pond will backwater to. Adjust crest elevation as necessary to achieve desired size of pond, inundation extent, and overflow patterns. If concerned about head drop (water surface elevation difference) over BDA, build a secondary BDA downstream with a crest elevation set to backwater into base of this BDA (and lessen head drop or elevation difference between water surface in pond and water surface downstream of BDA).
2. Build up first layer or course by widening base upstream and downstream of crest to flat height of 6 to 12" above existing water surface, and make sure it holds back water.
    a. If larger key pieces (i.e. larger logs, cobble or small boulders) are locally abundant, these can be used to lay out the crest position across the channel (as in Figure 32). Optionally, they can be 'keyed' in by excavating a small trench (no need to be deeper than ~1/3 of the height of key piece diameter) and place key pieces in and pack with excavated material.
    b. Lay out first layer of larger fill material, being careful not to go to higher than 6" to 12" above existing water surface. The first layer should be just high enough to backwater a flat water surface behind it.
    c. Using mud, bed material & turf (typically sourced from backwater area of pond) as fine fill material to plug up leaks, combine with sticks and branches of various sizes to build a wide base. Make sure base is wide enough to accommodate anticipated dam height (most dams will have a 1.5:1 to 3:1 (horizontal : vertical) proportions.
    d. Build up first layer only to top of key pieces from first layer. Make sure the crest is level across the channel and water is pooling to this temporary crest elevation.
3. Build up subsequent layer(s) in 6" to 12" lifts, packing well with fine fill material until ponding water to its next temporary crest elevation.
4. Repeat step 3 as many times as necessary to build up to design crest elevation.
5. Work a willow mattress (laying branches parallel to flow) into dam on downstream side and build to provide energy dissipation to overtopping flows.
6. If desired, and time permits, attempt to plug up BDA with mud and organic material (small sticks and turf) to flood pond to crest elevation. Optionally, you can leave this for maintenance by beaver or for infilling with leaves, woody debris and sediment.

Options, Considerations & Variations:

- For Step 2a, it is not necessary to build with larger key pieces (as in Figure 32) and plenty strong with a mix of smaller woody material and fine fill material (e.g., Figure 30). If woody key pieces are used, make sure to at least limb (cut off branches) on side in contact with bed.
- For Step 2b, if key pieces are limbed on the side that is in contact with bed, the branches removed from the other side can be used to help weave and wedge material in subsequent layers in. If this is done, make sure that limbs are trimmed at end to design crest elevation.
- Just like natural beaver dams, there are a huge number of variations in the woody fill material and fine fill material. In some riverscapes that lack woody riparian vegetation, or nearby woody material, beaver build very strong beaver dams out of nothing more than fine fill material.
- If building a 'primary' dam (larger dam that tends to be deep enough to support an underwater entrance to a beaver lodge, consider backwater inundation extents relative to good bank-lodging opportunities (e.g., overhanging banks, vegetation and cover from predation).
- If building multiple dams (typically secondary) in series, the dams within a complex tend to be positioned (spacing downstream) and built to heights that support flatwater from the crest of the downstream dam all the way upstream to the base of the next dam upstream.

Notes

- The temptation is always to build up (in height) quickly without making sure each layer is holding back water well and is stable. A better dam results in building up to the design crest elevation slowly.
- Overall dam height is best not to exceed the height of the people constructing it.
- It is easier to build in systems that already have a perennial water source and flowing water, as you can see instantly how well your structure backs up water. It is possible to build in intermittent channels or areas you expect to receive water in the future, but you will not immediately mimic a beaver pond in such situations.
- Much of the 'strength' of the dam comes from the messy carbon fiber matrix you are building with a mix of size and type of materials combined. Similar to concrete, the cement by itself is not strong, but the aggregate and/or reinforcing rebar is what gives the structure its strength.
- Resist the temptation to overbuild the BDA.
- A BDA that 'breaches' or 'blows out', just like natural beaver dams do, is not a 'failure' if designed to accommodate such a response. Often, BDAs that blow out or breach provide improved and more complex habitat.
- Design life: < 1 year (note actual life may last many years or even decades).

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PROJECT: NORTH SAND CREEK RIPARIAN RESTORATION LTPBR STRUCTURES REACHES 3-4

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Post-Assisted BDA

Some practitioners who build BDAs have become very accustomed to using posts, because that's how the first details they saw of BDAs were built and they stuck to the post-line wicker-weave recipe (Figure 36 Appendix C and Figure 19). Posts can provide some temporary anchoring and stability to help with high flows in systems with flashier flow regimes or that produce larger magnitude floods. However, in many situations beaver can produce plenty strong dams without posts. For situations where additional support during high flows is deemed necessary, our suggested practice is to start out following the instructions to build a postless BDA, and then simply add posts (Figure 34 & Figure 35).

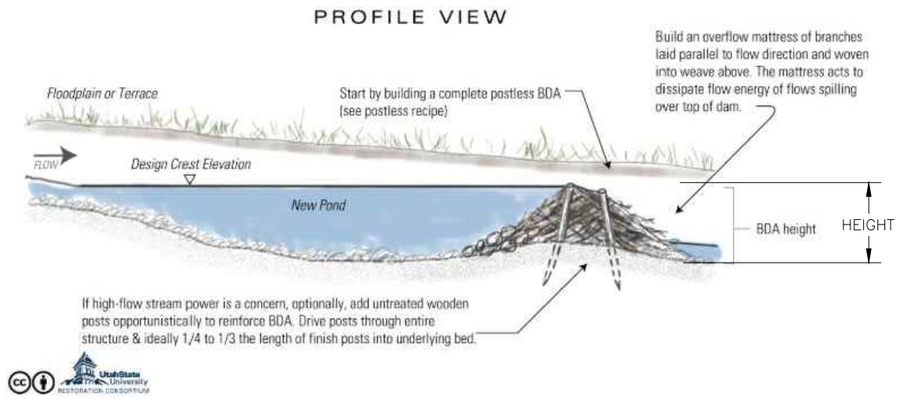

Figure 34 - Profile schematic of post-assisted BDA. If you think you need posts, our preferred approach is to build a postless BDA as per Figure 31, and then reinforce after the fact with some posts driven through the structure.

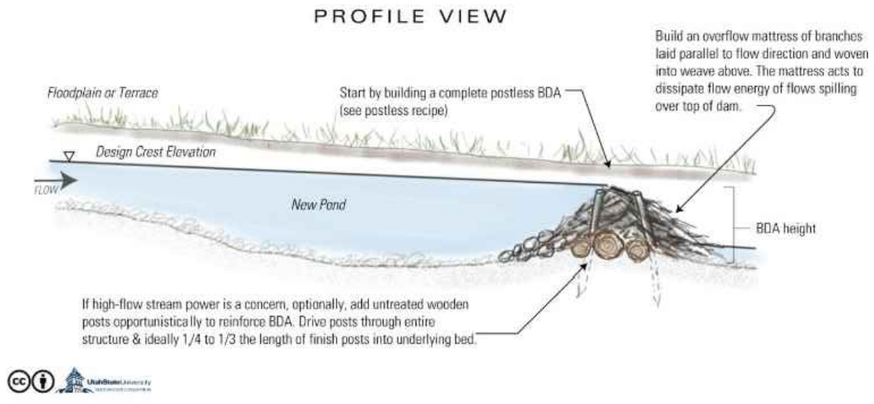

Figure 35 – Profile schematic of post-assisted BDA with key pieces. If you think you need posts, our preferred approach is to build a postless BDA as per Figure 33, and then reinforce after the fact with some posts driven through the structure.

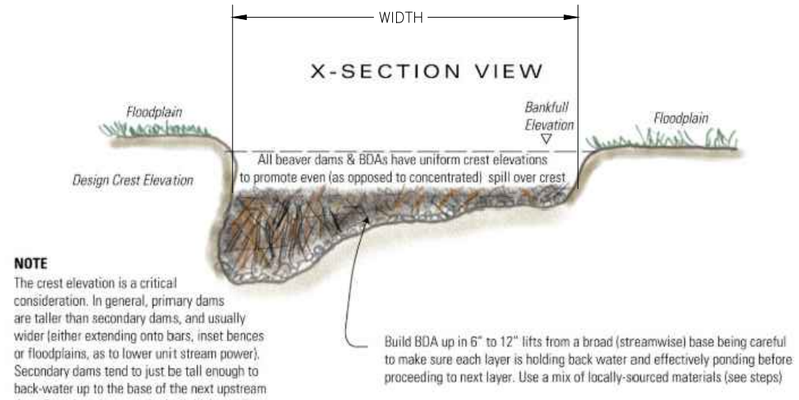

Figure 32 – Typical schematic sketches of a postless BDA with key pieces used in base.

NOTES:

- USE DR. WHEATON'S "LOW-TECH PROCESS-BASED RESTORATION OF RIVERSCAPES: DESIGN MANUAL" FOR MORE INFORMATION ABOUT STRUCTURE INSTALLATION
- BEAVER DAM ANALOGUES (BDAS) – PERMEABLE, CHANNEL-SPANNING STRUCTURE WITH A CONSTANT CREST ELEVATION, CONSTRUCTED WITH A MIXTURE OF WOOD DEBRIS AND FILL MATERIAL TO FORM A POND AND MIMIC A NATURAL BEAVER DAM

NOTES:

- PALS AND BDAS ARE HAND-BUILT STRUCTURES. THAT MIMIC AND PROMOTE WOOD ACCUMULATION. THEY ARE PERMEABLE.
- A HYDRAULIC POST-POUNDER WILL BE NECESSARY FOR INSTALLATION OF THE STRUCTURES.
- WOOD SHOULD GENERALLY BE HARVESTED LOCALLY. WOODY DEBRIS STRUCTURES CAN BE CONSTRUCTED FROM A VARIETY OF MATERIALS, AND THIS SITE PROVIDES MULTIPLE SOURCES OF CONIFER, WILLOW, ASPEN, AND EXTENSIVE GROUND JUNIPER THAT IS SUITABLE FOR CONSTRUCTION.
- CHANNEL-SPANNING STRUCTURES SHOULD INCORPORATE A VARIETY OF MATERIAL SIZES WITH LARGE WOODY DEBRIS FORMING THE BASE STRUCTURE AND USING AMPLE SMALLER MATERIAL AND FINES TO CLOG PORE SPACE IN THE STRUCTURE.
- UNTREATED WOODEN POSTS WOULD BE USED FOR PINNING IN AND SECURING THE WOOD STRUCTURES, AND IT IS RECOMMENDED THAT THESE MATERIALS ARE IMPORTED.

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APPROVED BY:
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REVISION: | DATE: | BY: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8

PROJECT: NORTH SAND CREEK RIPARIAN RESTORATION LTPBR STRUCTURES REACHES 3-4

SHEET TITLE: TYPICAL DETAILS - BDAS

LEGAL:
SEC.:6, 7
T10N-R78W
6TH P.M.
JACKSON COUNTY, CO

DATE: 5/6/2026

LISTED SCALES ACCURATE ON 24"X36" SHEET SIZE

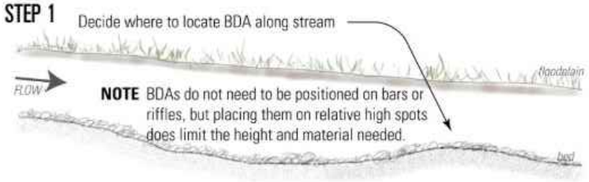
DU PROJECT NUMBER: CO-360-101

SHEET NUMBER: 9 OF 11

FILE LOCATION: C:\Users\tparker\OneDrive – Ducks Unlimited Incorporated\!_Personal_Projects\(CO-360-100) North Sand Creek Restoration Collaborative\Plans and Drawings\Sheets\CO-360-100_NorthSandCreek_Reaches3-4_SHEETS.dwg

PROFILE VIEW

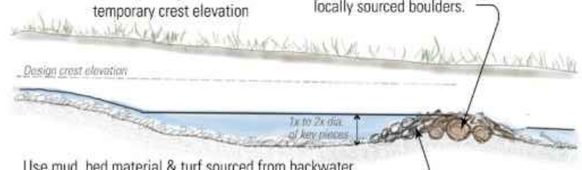
STEP 1 Decide where to locate BDA along stream



NOTE BDAs do not need to be positioned on bars or riffles, but placing them on relative high spots does limit the height and material needed.

STEP 2 Build up first layer only to top of key pieces and make sure crest is level across bed and its pooling water to this temporary crest elevation

Dig out a key to about 1/3 the depth of some large key pieces of wood or locally sourced boulders.



Use mud, bed material & turf sourced from backwater area combined with sticks of various sizes to build wide base. Make sure base is wide enough to accommodate designed height.

STEP(S) 3 Build up subsequent layer(s) in 6 to 12" lifts, packing well with mud, turf, leaves, needles, sediment and other material until ponding water to this next temporary crest elevation.

Lay branches parallel to flow on downstream side and build up a mattress to dissipate overflow

FINISHING STEP Bring dam up to desired design crest elevation. Make sure crest of dam is perfectly level (so no preferential flow or weir exists). If stream is flowing, water should be backed up and ponding, but flow over and through dam should equilibrate so that flow into pond equals flow out (over and through leaky dam).

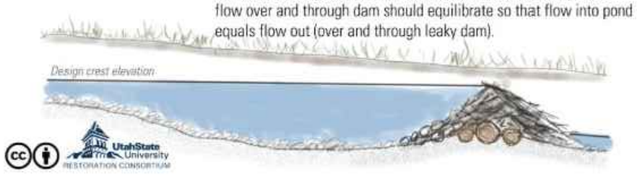
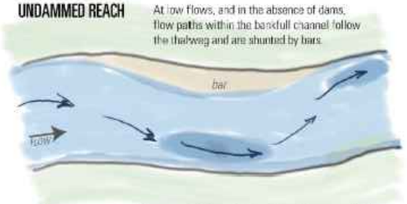


Figure 33 – Sequence for building postless BDAs with key pieces, build up in 6" to 12" lifts, slowly, like beaver do. Make sure that your lifts are level, and water is backed up sufficiently that is flowing over the crest evenly (as opposed to through or under the dam), and the base is broad, before building up to your next layer.

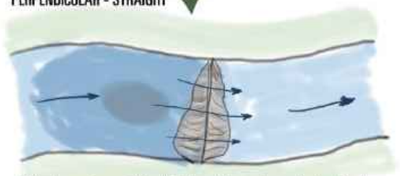
DAM CREST ORIENTATIONS

UNDAMMED REACH At low flows, and in the absence of dams, flow paths within the bankfull channel follow the thalweg and are shunted by bars.



Since dams are built to a constant crest elevation, they essentially are a contour. Water flows perpendicular to the contour and over the dam crest, when the dam is maintained and/or intact.

PERPENDICULAR - STRAIGHT ✓

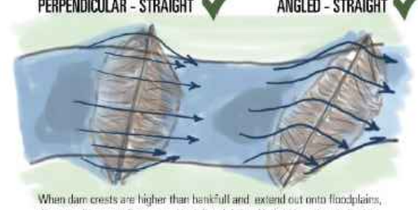


When dam crests span the bankfull channel, but are lower elevation than the adjacent floodplain, low flows are contained within the channel. Perpendicular orientations will back water up, and alter the flow paths to that of bankfull flows.

PERPENDICULAR - TO LOW FLOW ✓

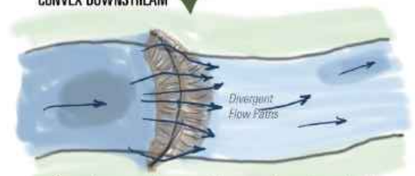
Smaller dams that just backup the low-flow channel, is often have an orientation perpendicular to the low flow, but at an angle to the bankfull flow patterns.

PERPENDICULAR - STRAIGHT ✓ **ANGLED - STRAIGHT** ✓



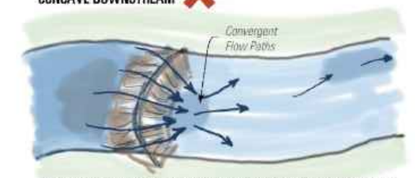
When dam crests are higher than bankfull and extend out onto floodplains, they can direct overflow onto those floodplains. However, a perpendicular, straight dam will direct most flow straight downstream. By contrast an angled dam will direct flow to one side of the channel (however the head drop tends to diss-pate most of the flow energy).

CONVEX DOWNSTREAM ✓



Beaver dams are sometimes curved in a convex downstream orientation across the channel, which creates divrgent flow paths over the dam. This flow pattar is effective at dissipating energy.

CONCAVE DOWNSTREAM ✗



Beavers rarely build dams like Hoover Dam (and Hoover was not designed to withstand spill over the top). Concave downstream crests concentrate flow at the base of the dam, scouring out a deep pool, but also potentially undermining the dam integrity.

PLAN VIEW

Figure 39 – BDAs can be built with various crest orientations (perpendicular, angled, convex downstream). Since a BDA crest is essentially a contour line (a line of equal elevation), flow paths will flow perpendicular over the crest. As such, if the intention is to direct flows in particular directions, think about your crest layout.

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PROJECT: NORTH SAND CREEK RIPARIAN RESTORATION LTPBR STRUCTURES REACHES 3-4

SHEET TITLE: TYPICAL DETAILS - BDAS

LEGAL:
SEC.:6, 7
T10N-R78W
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JACKSON COUNTY, CO

DATE: 5/6/2026

LISTED SCALES ACCURATE ON 24"X36" SHEET SIZE

DU PROJECT NUMBER: CO-360-101

SHEET NUMBER: 10 OF 11

Guidelines for Post Placement

If a post-assisted BDA or post-line wicker weave is used, one of the critical construction considerations is how the posts are driven, and whether a staggered double-row placement is used (Figure 40). We prefer double rows of posts staggered because they encourage construction of a wider based (streamwise) dam, and avoid building a wall. Also, if posts are driven in at angle, make sure they tilt inward toward the crest of the dam.

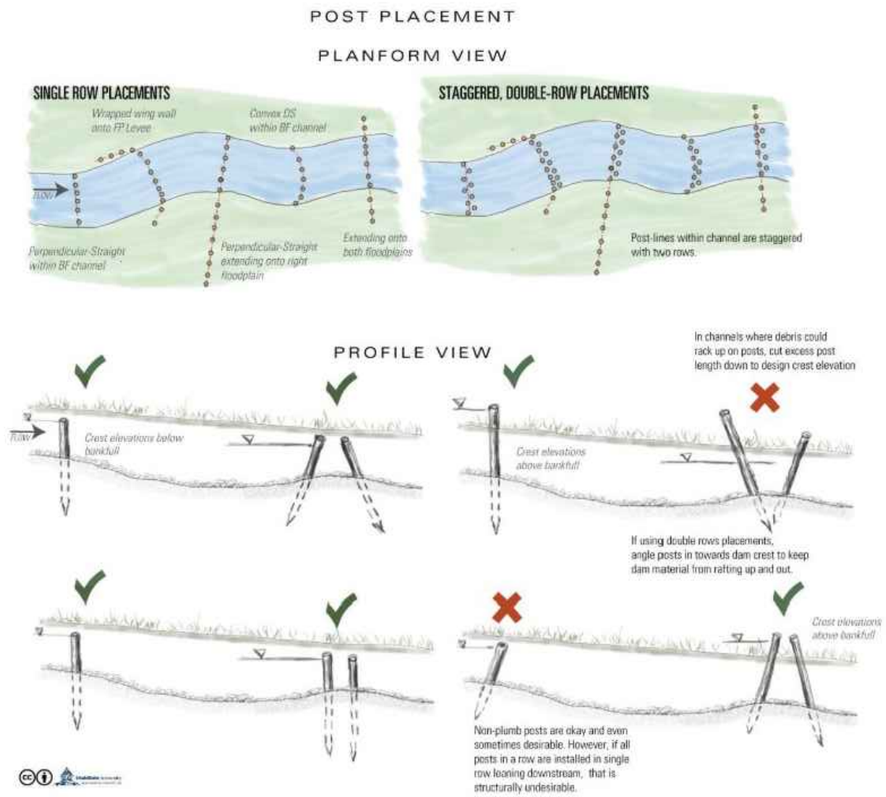

Figure 40 – Post placement considerations. When post are used in BDAs, consideration should be given to whether single-row or staggered double-row placements are used.

Figure 6 - Representative photos of the diversity of possible BDA shapes, sizes, locations, and building material. (A) post-assisted and willow weave (B) postless, sage and juniper (C) postless willow, using existing willow for stability (D) postless, juniper (E) post-assisted and juniper (F) postless willow and juniper (G) postless juniper (H) postless sage.

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