COLORADO
Colorado Water Conservation Board
Department of Natural Resources

1313 Sherman Street
Denver, CO 80203

P (303) 866-3441
F (303) 866-4474

John Hickenlooper, Governor

Robert Randall, DNR Interim Executive Director

James Eklund, CWCB Director

TO: Colorado Water Conservation Board Members

FROM: Ted Kowalski; Chief Interstate, Federal & Water Information Section
Steve Miller; Interstate, Federal & Water Information Section

DATE: March 16 -17, 2016 Board Meeting

AGENDA ITEM: **19. SB-195 South Platte Phreatophyte Study, Interim Report to General Assembly**

Background: SB 14-195, signed by Governor Hickenlooper on June 6, 2014, directs the Board to: "*conduct at least the preliminary stages of a comprehensive study to evaluate the growth and identification of phreatophytes along the South Platte River in the aftermath of the September 2013 flood*". Additionally, the bill requires that: "*the Board shall prepare a progress report and present it to a joint meeting of the House of Representatives Committee on Agriculture, Livestock, and Natural Resources and the Senate Committee on Agriculture, Natural Resources, and Energy, or their successor committees, during the second regular session of the Seventieth General Assembly in 2016*". Staff has prepared a draft of the requisite progress report and presents it for Board review and comment prior to delivery to the relevant committees of the General Assembly. A copy of the full text of SB195 is included in the progress report.

Discussion: The progress report describes the following aspects of the study:

- Outline of SB 14-195 objectives
- Development of the study scope of work and budget
- Summary of meetings and timeline
- Consultant agreements
- Summary of accomplishments by consultant task
- Schedule for completion by December 31, 2016
- Additional considerations

To date the field inventory work has been completed and preliminary GIS products for the pre-flood condition have been developed. New mapping from 2015 of the post flood condition is being processed. From these products a model will be developed and calibrated to estimate current and pre-flood density of all phreatophytes in the S. Platte Basin from the Ft. Lupton area to the Nebraska Stateline. The draft report is currently undergoing internal staff review and will be provided to the Board during the week of March 7.

Staff recommendation: Staff recommends that the Board review the draft report, provide comments and suggestions for finalizing the progress report, and approve the process for presentation to the General Assembly.

NOTE: The governor signed this measure on 6/6/2014.

SENATE BILL 14-195

BY SENATOR(S) Nicholson and Renfroe,;
also REPRESENTATIVE(S) Singer and Sonnenberg, DelGrosso, Foote, Humphrey, Young, Becker, Conti, Coram, Court, Fields, Gardner, Gerou, Ginal, Holbert, Kagan, Labuda, Landgraf, Lawrence, Lee, May, Melton, Murray, Pettersen, Primavera, Priola, Rosenthal, Saine, Salazar, Schafer, Scott, Stephens, Swalm, Vigil.

CONCERNING A STUDY OF PHREATOPHYTE GROWTH ALONG THE SOUTH PLATTE RIVER IN THE AFTERMATH OF THE SEPTEMBER 2013 FLOOD.

Be it enacted by the General Assembly of the State of Colorado:

SECTION 1. In Colorado Revised Statutes, 37-60-115, **add** (9) as follows:

37-60-115. Water studies - rules - repeal. (9) (a) THE BOARD SHALL CONDUCT AT LEAST THE PRELIMINARY STAGES OF A COMPREHENSIVE STUDY TO EVALUATE THE GROWTH AND IDENTIFICATION OF PHREATOPHYTES ALONG THE SOUTH PLATTE RIVER IN THE AFTERMATH OF THE SEPTEMBER 2013 FLOOD. IF APPROPRIATE, THE BOARD SHALL CONDUCT ALL STAGES OF THE STUDY. THE OBJECTIVES OF THE STUDY ARE:

(I) TO EVALUATE A PORTION OF THE WATERSHED ALONG THE SOUTH

_____
Capital letters indicate new material added to existing statutes; dashes through words indicate deletions from existing statutes and such material not part of act.

PLATTE RIVER THAT WAS AFFECTED BY THE SEPTEMBER 2013 FLOOD TO DETERMINE THE RELATIONSHIP BETWEEN HIGH GROUNDWATER AND NONBENEFICIAL CONSUMPTIVE USE BY PHREATOPHYTES; AND

(II) UTILIZING THE DATA COMPILED FOR SUBPARAGRAPH (I) OF THIS PARAGRAPH (a), TO DEVELOP A COST ANALYSIS FOR THE REMOVAL OF UNWANTED PHREATOPHYTES ALONG THE SOUTH PLATTE RIVER.

(b) THE BOARD MAY ENTER INTO CONTRACTS WITH COLORADO STATE UNIVERSITY'S BIOAGRICULTURAL SCIENCES AND PEST MANAGEMENT PROGRAM TO CONDUCT, OVERSEE, AND COORDINATE ALL ASPECTS OF THE STUDY AND SHALL COORDINATE WITH THE DEPARTMENT OF AGRICULTURE AND WEED MANAGEMENT SPECIALISTS FROM AFFECTED LOCAL GOVERNMENTS.

(c) THE BOARD SHALL COMMISSION THE STUDY AS SOON AS PRACTICABLE. THE BOARD SHALL PREPARE A FINAL REPORT, INCLUDING ITS CONCLUSIONS, AND PRESENT IT TO THE GENERAL ASSEMBLY NO LATER THAN DECEMBER 31, 2016. THE BOARD SHALL PREPARE A PROGRESS REPORT AND PRESENT IT TO A JOINT MEETING OF THE HOUSE OF REPRESENTATIVES COMMITTEE ON AGRICULTURE, LIVESTOCK, AND NATURAL RESOURCES AND THE SENATE COMMITTEE ON AGRICULTURE, NATURAL RESOURCES, AND ENERGY, OR THEIR SUCCESSOR COMMITTEES, DURING THE SECOND REGULAR SESSION OF THE SEVENTIETH GENERAL ASSEMBLY IN 2016.

(d) THE BOARD IS AUTHORIZED TO ACCEPT AND EXPEND GIFTS, GRANTS, AND DONATIONS FOR THE PURPOSES OF THIS SUBSECTION (9). THE GENERAL ASSEMBLY FINDS THAT THE IMPLEMENTATION OF THIS SUBSECTION (9) IS NOT ENTIRELY DEPENDENT ON THE RECEIPT OF ANY GIFTS, GRANTS, AND DONATIONS. THE BOARD SHALL TRANSMIT ALL MONEYS RECEIVED THROUGH GIFTS, GRANTS, OR DONATIONS TO THE STATE TREASURER, WHO SHALL CREDIT THEM TO THE COLORADO WATER CONSERVATION BOARD CONSTRUCTION FUND CREATED IN SECTION 37-60-121.

(e) THIS SUBSECTION (9) IS REPEALED, EFFECTIVE JULY 1, 2017.

SECTION 2. In Session Laws of Colorado 2012S, section 7 of chapter 1, **amend** (1) as follows:

Section 7. **Phreatophyte control cost-sharing program -**

appropriation. (1) In addition to any other appropriation, there is hereby appropriated, out of any moneys in the Colorado water conservation board construction fund not otherwise appropriated, to the department of natural resources, for allocation to the Colorado water conservation board, for the fiscal year beginning July 1, 2012, the sum of $1,000,000, or so much thereof as may be necessary, for the board to continue financing phreatophyte control cost-sharing grants AND TO EVALUATE THE GROWTH AND IDENTIFICATION OF PHREATOPHYTES ALONG THE SOUTH PLATTE RIVER IN THE AFTERMATH OF THE SEPTEMBER 2013 FLOOD through any of the board's existing programs.

SECTION 3. Safety clause. The general assembly hereby finds,

determines, and declares that this act is necessary for the immediate preservation of the public peace, health, and safety.

Morgan Carroll PRESIDENT OF THE SENATE	Mark Ferrandino SPEAKER OF THE HOUSE OF REPRESENTATIVES
Cindi L. Markwell SECRETARY OF THE SENATE	Marilyn Eddins CHIEF CLERK OF THE HOUSE OF REPRESENTATIVES

APPROVED_____

John W. Hickenlooper
GOVERNOR OF THE STATE OF COLORADO

STATE OF COLORADO
Department of Natural Resources

ORDER
Number: POGG1 PDAA 20150000000000000257
Date: 04/02/15
Description:
PDAA7000 tamarisk grant study effects of 2013 flood
Effective Date: Expiration Date:

BUYER
Buyer:
Email:

VENDOR
COLORADO STATE UNIVERSITY
2002 CAMPUS DELIVERY
FORT COLLINS, CO 80523 2002

Contact: Lori Mitchell
Phone: 970 491 6586

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BILL TO
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DENVER, CO 80203

SHIPPING INSTRUCTIONS
Delivery/Install Date:
F.O.B:
VENDOR INSTRUCTIONS:

Line Item	Commodity/Item Code	UOM	QTY	Unit Cost	Total Cost	MSDS Req.
1	G1000		0	0.00	$99,733.00	☐

Description: PDAA7000 tamarisk grant study effects of 2013 flood

Service From: 04/02/15 Service To: 12/31/16

TERMS AND CONDITIONS
https://www.colorado.gov/osc/purchase-order-terms-conditions

DOCUMENT TOTAL = $99,733.00

Scope of Work
SB14-195 Study Phase 1
Colorado State University
S. Platte Phreatophyte Survey

Purchase Order Amount: $99,733

CWCB Funding Source: 2012 Construction Fund Bill Section 7, SB12S-002
Invasive Phreatophyte Control Program (IPCP)

Contractor:
Colorado State University (CSU)
Office of Sponsored Programs
2002 Campus Delivery
Fort Collins, CO 80523-2002
Marilyn Morrissey, Senior Research Administrator
Phone: (970) 491-2375 | Fax: (970) 491-6147
Email: Marilyn.morrissey@colostate.edu

Project Description:
In 2014 the Colorado State legislature directed that the CWCB study the effects of the 2013 South Platte flood on phreatophytes, and develop cost estimates for removing non-native phreatophytes from the South Platte River. Following the September 2013 floods, there is concern that new sediment deposits and altered stream banks will increase the abundance of non-native species, including woody phreatophytes and State of Colorado listed noxious weeds. An increase in phreatophyte abundance has the potential to consume more groundwater via evapotranspiration. In this Phase of the SB14-195 study CSU will survey the river system for native and non-native phreatophytes and Colorado state-listed weed species at 15-20 sites along the South Platte River and its tributaries from Longmont to the Colorado-Nebraska border

Task Descriptions:
See attached proposal entitled "South Platte Phreatophyte Survey", dated March 13, 2015 for detailed task descriptions.

Deliverables:
See attached proposal entitled "South Platte Phreatophyte Survey", dated March 13, 2015 for description of deliverables.

Task Schedule: Complete all tasks by September 30, 2016. See attached proposal for more detailed schedule

Payment Schedule: CWCB will reimburse CSU up to a maximum of $99,733 for the tasks described above on a monthly basis.

South Platte Phreatophyte Survey
March 13, 2015

Andrew Norton[1], Gabrielle Katz[1], Ahmed Eldeiry[2], Reagan Waskom[2], Tom Holtzer[1]

1. Department of Bioagricultural Sciences and Pest Management, 1177 Campus Delivery Colorado State University, Fort Collins CO.
2. Colorado Water Institute, 1033 Campus Delivery, Colorado State University, Fort Collins CO

I. Project Objectives:

1) Create a written review of the existing literature on the association between river hydrology and native and non-native phreatophyte establishment and growth, emphasizing issues of particular relevance to the South Platte River.

2) Determine the abundance and distribution of native and non-native woody phreatophyte species at twenty sites along the South Platte River, and establish the relationship between shallow ground water and phreatophyte presence and abundance.

3) Determine the frequency and severity of invasion by Colorado State listed noxious weeds at these same sites.

4) For both phreatophytes and listed weed species, determine the relationship between river geomorphic surface and species incidence and abundance, and examine the effects of the September 2013 flood on species recruitment.

5) Link these data to GIS-based maps of the South Platte flood plain, and use these maps to predict the abundance of non-native phreatophytes and listed weeds along and within the river system.

6) Obtain data from existing groundwater monitoring wells from before and after the 2013 flood and determine if there has been a measurable change in water table depth within the flood-affected region.

II. Background

In 2014 the Colorado State legislature appropriated funds to study the effects of the 2013 South Platte flood on phreatophytes, and the feasibility of removing non-native phreatophytes from the South Platte River. Following the September 2013 floods, there is concern that new sediment deposits and altered stream banks will increase the abundance of non-native species, including woody phreatophytes and State of Colorado listed noxious weeds. An increase in phreatophyte abundance has the potential to consume more groundwater via evapotranspiration. Phreatophytes are deep-rooted plants that access a substantial portion of their water needs from ground water sources. The presence of other, undesirable weed species has the potential to increase the cost and complexity of phreatophyte removal, by necessitating post-removal follow up treatments.

To address these concerns, we propose to survey the river system for native and non-native phreatophytes and Colorado state-listed weed species. We will survey 15-20 sites along the

South Platte River from Denver to the Colorado-Nebraska border. Survey data will then be used to generate a GIS-based map predicting the probability of weed presence and abundance for these species along the entire length of the river in the study area. Within river systems, particular plant species are often associated with specific geomorphic surfaces. For example, *Tamarix* sp., cottonwood and willow all require newly exposed sand bars with a shallow water table in order to germinate and establish. In contrast, Russian olive will germinate and can establish on sand bars, but is also able to establish on terraces farther away and higher above the river. Similarly, the distribution and abundance of herbaceous species is affected by geomorphic position within river corridors. Our survey will delineate the geomorphic surfaces and locations colonized by undesirable species.

In 2013 the Colorado Water Institute completed a study of ground water levels within the South Platte River Basin. Their report, *HB12□1278 Study of the South Platte River Alluvial Aquifer*, (available at http://www.cwi.colostate.edu/southplatte) examines the history and current status of groundwater use and water table depth in the South Platte basin. One of the products of this work is a map of estimated groundwater depth for the basin. These data will be used in combination with plant surveys and remote sensing data to determine what proportion of the shallow-water areas of the study area are currently occupied by phreatophytic vegetation.

We propose to collect data on the distributions of both native and non-native woody phreatophytes, as well as state listed weed species because we expect all of these functional groups to be present in the system. Further, all of these groups should be considered in developing a management plan for South Platte vegetation. Appropriate removal techniques for non-native phreatophytes and associated costs will vary depending on the presence of desirable native phreatophytes. Predicting where follow-on treatments for listed weed species and/or active restoration will be needed depends largely on the presence and abundance of weeds prior to phreatophyte removal at each site.

III. Methods

A. Field survey

15 - 20 study sites will be selected in consultation with the state of Colorado's noxious weed program, County weed managers, extension agents, and other stakeholders. Sites will be selected to span the range of conditions typical of the River in the study area (the St. Vrain River near Longmont, the Poudre River near Fort Collins to the South Platte River at Colorado/Nebraska line). Where feasible, sites used in previous surveys of the South Platte or sites located near existing monitoring wells will be included in the project. At each site, we will define a sample area that is a 500 m section along the river. Within this sample area, we will establish three transects perpendicular to the river, spanning the riparian zone and ending at the edge of the upland.

Along each transect, we will quantify vegetation cover using the line-point-intercept method. Sampling points will be spaced ≤5 m apart along each transect, to yield a minimum of 500 sample points per study site. At each point, we will use a vertical pole to record the presence of vegetation touching the point in four height categories: (1) low vegetation (<1m), (2) mid-story vegetation (1-5m), (3) canopy (5-10m), and (4) high canopy (>10 m). Groundcover (e.g., silt, sand, gravel, cobble, plant litter) will also be recorded. All woody plants will be identified to species. Herbaceous vegetation will be characterized as grass or forb, except for State listed weed species which will be documented by species. The presence of Colorado State listed weed

species and woody phreatophyte seedlings will also be noted by exhaustive search within a 10 m belt along the entire length of each transect.

Stem density, basal area, frequency, importance and condition of woody species will be assessed at each site using the point centered quarter method. A minimum of thirty points per site will be sampled, spaced evenly along the transects. At each point, the distance to the nearest tree in each quarter (defined by the transect line, and a line perpendicular to the transect) will be measured. Tree species, basal diameter, and canopy condition will also be recorded. From these measurements, density, frequency and importance will be calculated for each woody species.

In addition to the above data, we will delimit representative polygons (clusters) of each phreatophyte species (e.g., cottonwood, Russian olive) present at each site for use as training samples for the remote sensing approach to phreatophyte mapping. At least three areas for each individual species will be delineated at each site, regardless of density. Polygon perimeters will be recorded using GPS.

Because environmental gradients within riparian zones strongly affect plant distributions, each sample point will be categorized according to its geomorphic surface, and position relative to the channel thalweg. We will record the locations of each sample point with GPS, and will use these locations to map the sample points using GIS.

B. Remote sensing data

Aerial photographs from the 1930s will be used to record the location of the former braided channel bed, which has subsequently narrowed in conjunction with riparian forest establishment. More recent orthoimagery of the river corridor from 2013 (pre-flood) and 2015 will be used to identify areas of erosion and sediment deposition. These images will also be used in the GIS analysis to help identify portions of the corridor that are occupied by phreatophytes. Images (1 m resolution) will be obtained from the USGS National Map server or a third party vendor. We will use LiDAR data (available through http://coast.noaa.gov/inventory/#) to determine the height of each sample point relative to the channel thalweg. Geomorphic categories for sample points will include: channel bed (e.g., bars, islands), channel bank (e.g., channel shelf, cutbank), floodplain (e.g., depressions, abandoned channels), and upland terrace.

C. Ground water monitoring data

Data in HydroBase from groundwater monitoring wells and or surface gauges will be used to determine if the water table depth in the flood affected zone has changed significantly since the 2013 flood.

D. Data Analysis

Field data will be used to characterize South Platte River riparian vegetation, including native and non-native woody phreatophytes and listed weeds. We will determine the distribution and abundance of phreatophytes at the twenty study sites, and will use this information to generalize about the occurrence of phreatophytes on the specific geomorphic surfaces that characterize the river, the history of their establishment, and likely future trends. We will use size/age classes to assess the effects of geomorphic processes on establishment of woody species. For Colorado State listed weeds, we will determine their distribution and abundance at the study sites, and assess the possible effects of the 2013 flood on their occurrence.

E. Descriptive and Predictive Mapping

The presence and abundance of the phreatophyte species along the South Platte will also be assessed by generating an accurate land cover classified maps from multispectral high-resolution images. These classified maps will be used to create thematic maps that show the existence and distribution of the phreatophyte species along the river. The collected data from the 20 sites will be used as signatures to train the classification. Three approaches will be implemented and evaluated in generating classified maps. First, classified maps will be generated for each individual site with a length of 500 meter along the river using the collected data in that site. Second, the river will be divided into 20 reaches (with an approximate length of 15 miles for each reach) where the collection data site will be at the center of each reach and then each reach will be classified individually. Third, the whole river will be classified once using all data collected from the 20 sites. Two different classification algorithms will be implemented and evaluated. First, supervised and unsupervised or a combination of both. Second, Knowledge Engineering based expert system classification. The collected samples from the 20 sites will be used as ground truth data for image classification. The final classified images together with the groundcover collected data (silt, sand, gravel, etc.) as well as the extracted data from DEM and LiDAR will be used to investigate the relationship between the river geomorphic surface and the establishment and growth of phreatophyte and weed species.

The final classified maps will investigated with river hydrology maps (available at Colorado Decision Support System layers of groundwater table, soil, landuse, precipitation, etc.) to establish a relationship between the river hydrology and the abundance of non-native phreatophytes and listed weeds along and within the river system. The effects of the September 2013 flood on species recruitment will be assessed by comparing high resolution images acquired before and after the flood. These images will be classified using the approaches mentioned earlier only on the identified areas that effected by the flood. Spatial modeling will be used to analyze the changes between the images before and after the flood. Image difference and thematic change techniques will be used to quantify and assess the change caused by the flood.

These analyses will generate maps of phreatophytes and listed weed species that describe the current state of the river corridor and will also identify the environmental conditions most associated with phreatophyte weed presence and abundance. This latter information will be used to provide an assessment of those portions of the river corridor most at risk of future invasion. Current and projected distributions for phreatophytes will be compared with GIS layers for estimated groundwater depth prepared by the Colorado Water Institute and the USGS (see http://www.cwi.colostate.edu/southplatte/). The portion of the shallow water table areas within the basin currently occupied by phreatophytes will be determined. We will also determine the portion of these shallow water areas that are suitable for future colonization by phreatophytic vegetation.

IV. Time line

April 2015: Consult with county weed coordinators and extension personnel to select study sites.
May – August, 2015: Collect data on incidence and abundance of phreatophytes and weed species. Begin literature review.

August – December 2015: Data entry and analysis. Categorize geomorphic surfaces from aerial images and LiDAR data.
December 2015: Write progress report and summarize initial findings. Finish literature review.
January – May 2016: Model phreatophyte and weed incidence and abundance.
June, 2016: Draft final report, submit to CWCB for review and comment.
August, 2016: Complete final report, submit to CWCB.

V. Budget Narrative

A. Personnel

We request funds for 2 undergraduate research associates for 12 weeks each. These students will, under supervision of PIs Katz and Norton, be responsible for collecting data on phreatophyte and weed abundance at each of the 20 sites. These students will be paid $11.00 per hour for 3 months * 160 hours per month each for a total of $10,560. CSU fringe for student employees is 0.6%, or $63. Total undergraduate labor is **$10,623**.

We also request funds for PI Katz at 50% time for 5.5 months. Dr. Katz's full time salary is $8,333 per month. We request 0.5*5.5 months * $8,333, for a total of $22,916. CSU fringe for faculty and research associates is 25.4%, or $5,821 for PI Katz. The total salary and fringe request for Dr. Katz is **$28,737**. Dr. Katz will take the lead in creating the literature review (Obj. 1) and in training and supervising the undergraduate employees. She will also assist in data collection and verification as needed.

We request funds for PI Eldeiry for 10 months at 50% time, or $2,500 per month, for a total of $25,000. CSU fringe for faculty and research associates is 25.4%, or $6,350. The total salary and fringe request for Dr. Eldeiry is **$31,350**. Dr. Eldeiry will use field data and other GIS layers to create the GIS maps of phreatophyte and weed invasion, and will use existing data sets to determine if the 2013 flood has altered ground water depth in the flood affected areas.

We also request funds for PI Norton for 0.75 months at $9,222 per month, for a total of $6,917. CSU fringe for faculty and research associates is 25.4%, or $1,757. The total salary and fringe request for Dr. Norton is **$8,674**. Dr. Norton will assist in the hiring and training of undergraduates, and will work with Dr. Katz on the literature review (Obj. 1), and will take the lead on data analysis and report writing for Obj. 2 and 3.

Total salary and fringe requested is **$79,384.**

B. Travel

We request funds to travel to the 15-20 survey sites along the South Platte River. All costs below assume travel is from Fort Collins to the research sites. Approximately ½ of the research sites can be most efficiently surveyed using day trips. For sites more distant from Fort Collins we have budgeted over-night stays in motel rooms (2 persons per room) and the standard per diem for out of town trips.

We request funds to pay for a rental vehicle and mileage. We estimate 4 days per week for 12 weeks and 4,500 miles for a total of **$3,840**. Travel to sites more distant from Fort Collins will require overnight stays. We request funds to pay for 5 overnight stays in a motel plus per diem for a total of **$850**.
Total travel costs come to **$5,155.**

C. Materials and Supplies

High resolution orthoimagery is available at the county level. Images from 2013 are currently available from USDA at no cost. Images from 2015 will be purchased from a commercial vendor at a cost of $2,000.

Two 100 meter survey tapes. $74.50 each, total equals $149

Two forest survey dbh tapes, $18 each, for a total of $36.00

The total for request for Materials and Supplies equals **$2,185**

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D. Cost summary

The total direct costs requested to complete project objectives are **$86,724.** The CSU indirect cost rate for Colorado Water Conservation Board sponsored projects is 15% of total direct costs. The indirect costs for this project total **$13,009. . The total requested budget is $99,733**

STATE OF COLORADO
Department of Natural Resources

ORDER
Number: POGG1 PDAA 20160000000000000148
Date: 07/08/15
Description:
PDAA7000 Tamarisk grant IPCP technical assistance
Effective Date: 07/15/15 Expiration Date: 12/31/16

BUYER
Buyer:
Email:

VENDOR
TAMARISK COALITION
PO BOX 1907
GRAND JUNCTION, CO 81502-1907

Contact: .
Phone: 9702481685

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The order number and line number must appear on all invoices, packing slips, cartons and correspondence

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SHIPPING INSTRUCTIONS
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VENDOR INSTRUCTIONS:

Line Item	Commodity/Item Code	UOM	QTY	Unit Cost	Total Cost	MSDS Req.
1	G1000		0	0.00	$42,150.00	☐

Description: PDAA7000 Tamarisk grant IPCP technical assistance

Service From: 07/15/15 Service To: 12/31/16

TERMS AND CONDITIONS
https://www.colorado.gov/osc/purchase-order-terms-conditions

DOCUMENT TOTAL = $42,150.00

Scope of Work

GRANTEE - Tamarisk Coalition

PRIMARY CONTACT – Stacy Beaugh, Executive Director

ADDRESS – PO Box 1907, Grand Junction, CO 81502

PHONE – 970.256.7400

PROJECT NAME – IPCP Assistance, S. Platte SB 195 Phase II, S. Platte Pre-plan

GRANT AMOUNT - $42,150

INTRODUCTION AND BACKGROUND

Invasive Phreatophyte Control Program (IPCP) Technical Assistance:
Tamarisk Coalition (TC) will assist the Colorado Water Conservation Board's (CWCB) Invasive Phreatophyte Control Program (IPCP), by providing technical support to IPCP grantees as necessary.

TC will highlight partners implementing work through its mass emails and other outreach avenues. In order to continue funding for similar programs, TC will also provide technical assistance in the promotion of additional funding for riparian restoration.

S. Platte SB195 Study Phase II: Senate Bill 14-195 directed the CWCB to evaluate the growth of invasive phreatophytes along the S. Platte River in the aftermath of the September 2013 floods. TC will provide the principal researchers from CSU with technical assistance and support on the study of invasive phreatophytes in the S. Platte basin. Additionally, TC will develop cost estimates for the control of invasive phreatophytes, subsequent revegetation with native plant materials, and other restoration actions per the study findings. TC will compile the research and write the final report to CWCB.

S. Platte Basin Pre-planning: The Phreatophyte Subcommittee of the S. Platte Basin Roundtable is currently transitioning into new leadership. The group needs to identify leadership and capacity, planning and financial resources to begin implementation of an invasive phreatophyte control program. The CWCB is requesting assistance from the TC to explore who the potential leaders might be, what capacity is needed, and resources to consider before embarking on a full implementation plan for the S. Platte basin.

OBJECTIVES

Invasive Phreatophyte Control Program (IPCP) Technical Assistance:

- Provide recommendations to CWCB
- Conduct project performance monitoring during control and revegetation efforts
- Assist grantees with project implementation and trouble-shooting as requested
- Highlight projects undertaken by partner organizations
- Assist grantees in obtaining additional funding for woody invasives control work

S. Platte SB195 Study Phase II:

- Provide technical assistance and support to CWCB and principal researchers of the SB - 195 study
- Provide cost projections and control recommendations as per the findings of the SB-195 study
- Compile research and write a final report for CWCB

S. Platte Basin Pre-planning:

- Provide recommendations to basin and CWCB on the appropriate lead agency and capacity for invasive phreatophyte control efforts in the S. Platte
- Provide recommendations to basin and CWCB on the needed planning for implementation of control efforts in S. Platte

TASKS

Provide a detailed description of each task using the following format. Detailed descriptions are only required for CWCB funded tasks. Other tasks should be identified but do not require details beyond a brief description.

TASK 1 - Invasive Phreatophyte Control Program (IPCP) Technical Assistance:

Activities

- Assist CWCB in pre-construction meeting(s) to review projects with grant participants and support grantees with assistance as needed
- TC will provide technical assistance and support to IPCP grantees
- TC will promote the IPCP through various networks and provide updates on projects through its mass email and other outreach materials
- TC will research additional funding for riparian restoration projects that complement the IPCP grant program and distribute those opportunities to IPCP grantees via the Riparian Restoration Connection www.riparianrestoration.org. TC will assist IPCP grantees as they access and utilize the additional funding sources for match and leverage to the IPCP program.

Evaluation

- Articles on partners' projects will be published in a quarterly newsletter that is distributed via an electronic list serve and via other outreach avenues (e.g. Facebook).
- Status reports will be provided every 6-months documenting advances made in procuring additional funding.

TASK 2 - S. Platte SB195 Study Phase II:

- Provide riparian restoration technical assistance, support and expertise to the principal researchers of the SB -195 study. Provide support and consultation to CWCB on aspects of SB-195.
- Apply cost projections and control recommendations to the results and findings of the research and planning for SB-195.
- TC will encumber the body of research, mapping, and GIS data from the researchers on SB-195 and compile information into a final report to CWCB

Evaluation

- 6 Months status reports documenting achievements and assistance to CWCB and study principals.
- Documentation of cost projections and final report completion. Report will be completed by September 30, 2016, for CWCB's reporting requirements to the Colorado legislature, by December 31, 2016.

TASK 3 - S. Platte Basin Pre-planning:

- TC will interview organizations, agencies and basin representatives for basin specific knowledge and information that will assist in creating a basin recommendation document for invasive phreatophyte control and riparian restoration practices.
- TC will conduct outreach and planning sessions designed to gather stakeholders in the S. Platte basin and identify steps forward for a basin wide riparian restoration program.
- Provide recommendations to basin and CWCB on potential and appropriate lead agencies and capacity to plan, implement and monitor invasive phreatophyte control efforts in the S. Platte.

Evaluation

- S. Platte Basin recommendations document will be completed by Oct. 30, 2015 for use by the S. Platte Basin Phreatophyte SC and Basin Roundtable.

REPORTING AND FINAL DELIVERABLES

Reporting: Progress reports shall be submitted with each invoice describing work accomplished on each of the tasks identified in the statement of work including a description of any major issues that have occurred and any corrective action taken to address these issues.

Final Deliverables:
Task 1: A report containing photographs, summaries of meetings and reports/designs
Task 2: A final report meeting all requirements contained in SB14-195 and incorporating as appendices all work accomplished by CSU in Phase 1 of the study.
Task 3: A report containing summaries of meetings and recommendations for future planning activities and management.

South Platte Phreatophyte Survey

Andrew Norton[1], Gabrielle Katz[1], Ahmed Eldeiry[2], Reagan Waskom[2], Tom Holtzer[1]

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Progress Report – December 31, 2015

Background

In 2014 the Colorado State legislature appropriated funds to study the effects of the 2013 South Platte flood on phreatophytes, and the feasibility of removing non-native phreatophytes from the South Platte River. Following the September 2013 floods, there is concern that new sediment deposits and altered stream banks will increase the abundance of non-native species, including woody phreatophytes and State of Colorado listed noxious weeds. An increase in phreatophyte abundance has the potential to consume more groundwater via evapotranspiration. Phreatophytes are deep-rooted plants that access a substantial portion of their water needs from ground water sources. The presence of other, undesirable weed species has the potential to increase the cost and complexity of phreatophyte removal, by necessitating post-removal follow up treatments.

To address these concerns, we are surveying the river system for native and non-native phreatophytes and Colorado state-listed weed species. We will survey 15-20 sites along the South Platte River from Denver to the Colorado-Nebraska border. Survey data will then be used to generate a GIS-based map predicting the probability of weed presence and abundance for these species along the entire length of the river in the study area. Within river systems, particular plant species are often associated with specific geomorphic surfaces. For example, *Tamarix* sp., cottonwood and willow all require newly exposed sand bars with a shallow water table in order to germinate and establish. In contrast, Russian olive will germinate and can establish on sand bars, but is also able to establish on terraces farther away and higher above the river. Similarly, the distribution and abundance of herbaceous species is affected by geomorphic position within river corridors. Our survey will delineate the geomorphic surfaces and locations colonized by undesirable species.

Progress – Summary of data collected

We have completed field data collection, acquired 2013 LiDAR and aerial imagery for the entire study area. 2015 aerial imagery data will be available in 2016.

We collected tree, shrub, and noxious weed presence and abundance data from 873 10 x 20 meter plots over 15 sites. Plots were located on transects perpendicular to the river at each site. The sampling design and site locations are provided in figures 1 - 3. For each tree within the transects we recorded diameter at breast height (dbh), the percent of the tree canopy estimated to be alive and tree height. For shrubs less than 2 m tall we recorded stem diameter classes (<1 cm,

1 – 3 cm, >3 cm) and abundance. At many locations there were hundreds to thousands of stems present within each 10 x 20 m belt. In these cases we subsampled several representative 1 x 1 m areas and estimated total abundance by size class for an entire 10 x 20 m plot.

To measure weed abundance, we estimated weed abundance by collecting point data for any state of Colorado listed weed species every two meters along the transects. In addition, presence/absence of listed weeds was recorded in a 10 m x 10 m plot every 10 m along each transect. GPS coordinates were recorded every 10 m along the transects using a Trimble GeoXM and post-processed in TerraSync.

We have acquired LiDAR data for the entire study area. We are in the process of using regression techniques to create a map of tree and shrub abundance for the study area based on the survey data and LiDAR imagery.

We surveyed 873 plots over 15 sites, for a total of 175 hectares. Over all of these sites we collected dbh, height and canopy condition data from 2182 trees (Table 1). As expected, plains cottonwood is the dominant tree species in the South Platte floodplain, comprising more than 45% of the individuals recorded. Basal area (BA) is a common metric used to compare tree volume between sites, is a measure of the total the cross sectional area occupied by trunks at a site. Just over 80% of the total tree basal area for the study area is comprised of plains cottonwood, followed in abundance by peach leaf willow at nearly 12% of the total basal area. Non-native species comprise almost 6% of basal area over all sites.

Table 3 summarizes the shrub data collected. Coyote willow was the dominant shrub species found, with approximately 83% of all stems recorded being from this species. Snowberry was the next most abundant shrub species, with just over 14% of the total stems.

Abundance data for noxious weed species was also recorded. These data have been entered and we are in the process of validating and cross-checking them.

Progress - Literature review.

The literature review is in progress. To date, we have assembled literature on (1) the relationship between river hydrology and native and non-native phreatophyte establishment and growth, focusing on issues of particular relevance to the South Platte River, and (2) South Platte River riparian vegetation history and distributions. Synthesis of this body of research literature is in progress, and will be complete by submission of the final report.

Progress - Development of predictive, GIS-based models

Using the above survey data, we have developed initial models of woody basal area throughout the study area. All of the models were created from the relationship of forestry field plots and the associated LiDAR metrics. These models are applied to the forested portions of the of the study area. To designate forest and non-forest areas, each 20*20 meter pixel needs to contain

vegetation of at least 3 meter in height and have at least 2% canopy cover, and we then create an analysis mask to exclude non forest pixels from our model runs.

Next, we created a bare earth surface model. It provides the reference elevation for measuring the heights of features in the data. To do this we filter the data to remove the above-ground LiDAR returns, then create a Bare Earth Surface from the remaining (ground) LiDAR returns. This procedure is performed the Groundfilter program described in Kraus and Pfeifer (1998). The Bare Earth Surface model allows us to correlate LiDAR returns with vegetation height and density.

We then use multiple regression to predict forest basal area. These models take the form of

$$BA_i = \alpha_i + \beta_1 * L_{i,1} + \beta_2 * L_{i,2} + \beta_3 * L_{i,3} \ldots + \varepsilon_i$$

Where BA_i = measured basal area from survey data, β_{1-x} are coefficients that relate LiDAR metrics to basal area, L_{1-x} are different LiDAR metrics and ε are un-correlated normally distributed errors. There are a very large number of LiDAR metrics that can be used. Common ones used in forest mensuration are mean and median height, standard deviation in height, and 10, 25 50 75 and 90% height quantiles. Using the above model structure, the best models are selected using information theoretics (i.e. Akaike's Information Criterion – a measure of how much information a model contains or the coefficient of determination (R^2), which measures the amount of how well the data fit the model).

An example of the model output is illustrated in figure 4. This process is presented in the attached PowerPoint slides for sites 1, 11 and 13. We are in the process of selecting a single best model that will predict tree and shrub abundance over the entire study area.

Next steps

1) Model Colorado State-listed weed species incidence and abundance. This will occur starting in January, with an estimated completion by the beginning of May.

2) Integration of 2013 and 2015 aerial imagery with LiDAR based models to predict:
   a) The current distribution and abundance of phreatophytes throughout the entire study area
   b) The historical (pre-2013 flood) distribution and abundance of phreatophytes throughout the study area.
   c) Use a) and b) to determine change in phrteatophyte distribution and abundance throughout the study area.

Kraus, K. Pfeifer, P. 1998. Determination of terrain models in wooded areas with airborne laser scanner data. ISPRS Journal of Photogrammetry and Remote Sensing. 53(4):193-203

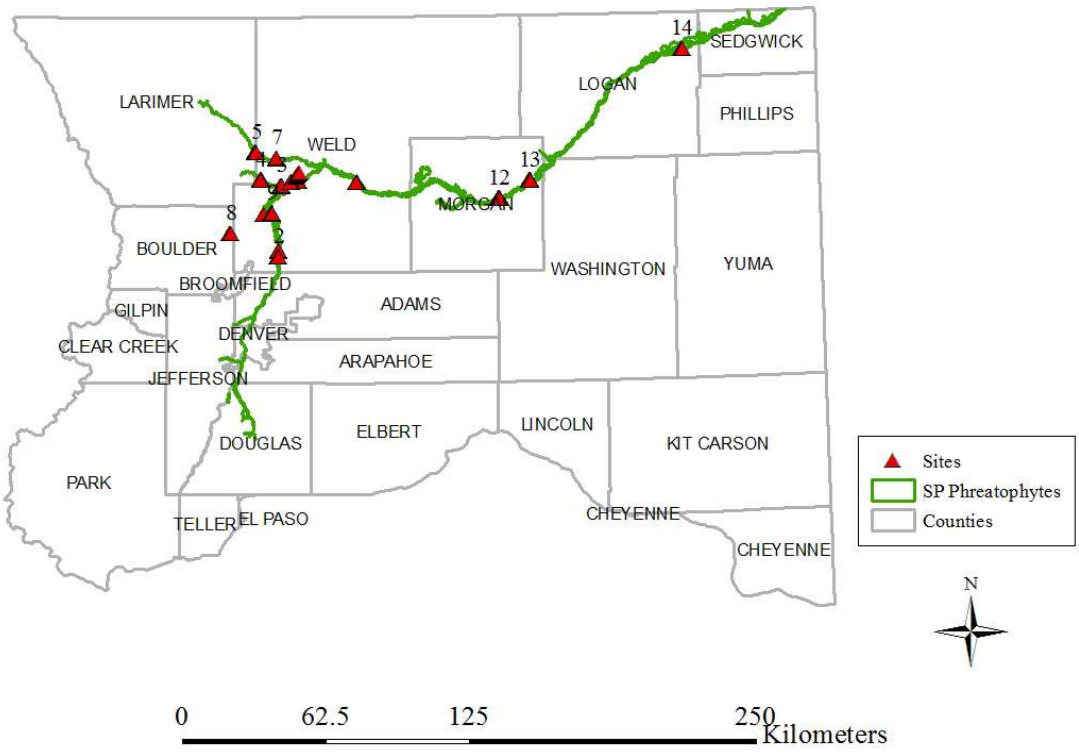


Figure 1. Site locations.

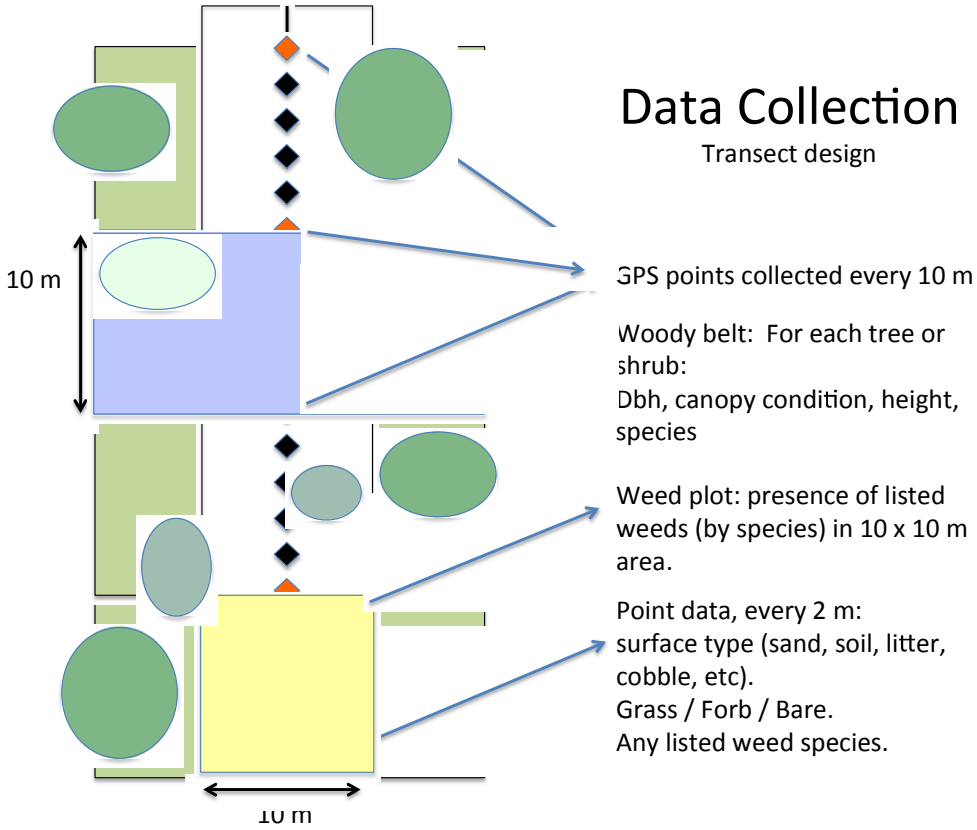


Figure 3. Transect sampling design. Transects are oriented perpendicular to the river at each site. Along the transects all tree and shrub species are measured within 10 x 20 m belts. Weed incidences is recorded every 2 m (point data) and within each 10 x 10 m block (incidence data). GPS coordinates are recorded every 10 m

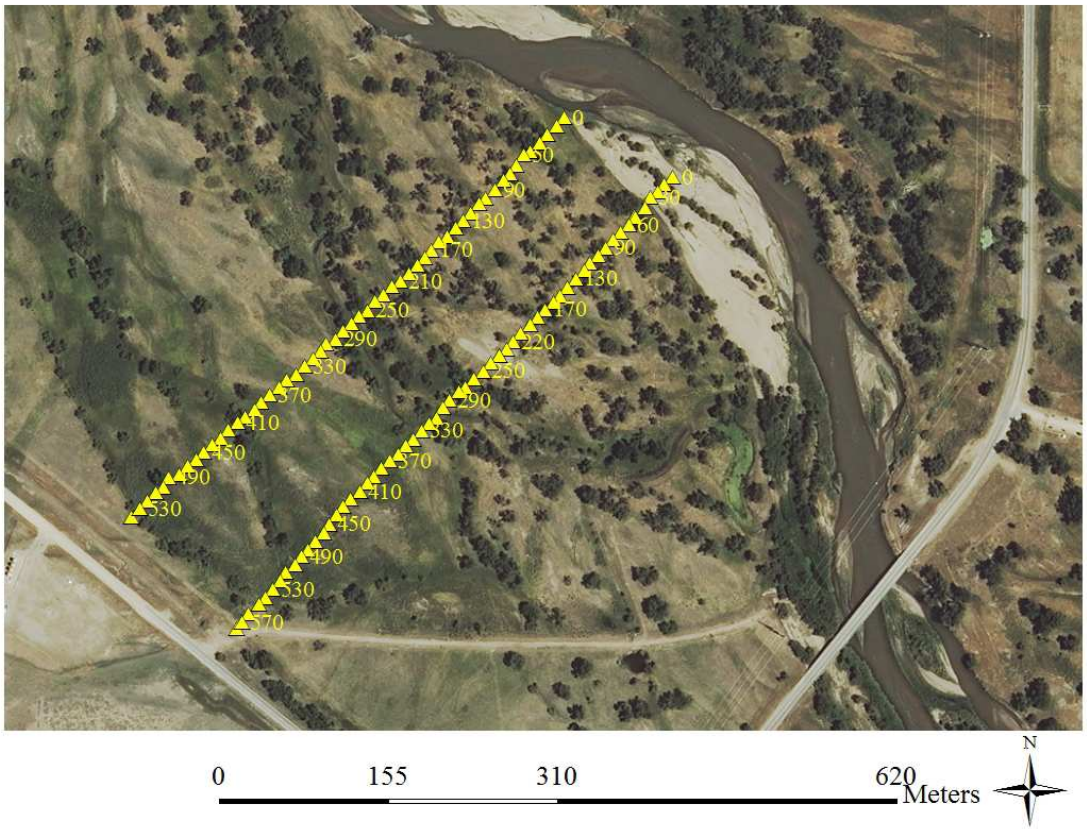


Figure 4: Example of transect sampling design from site 11. Yellow triangles are recorded GPS points taken every 10 m along transect.

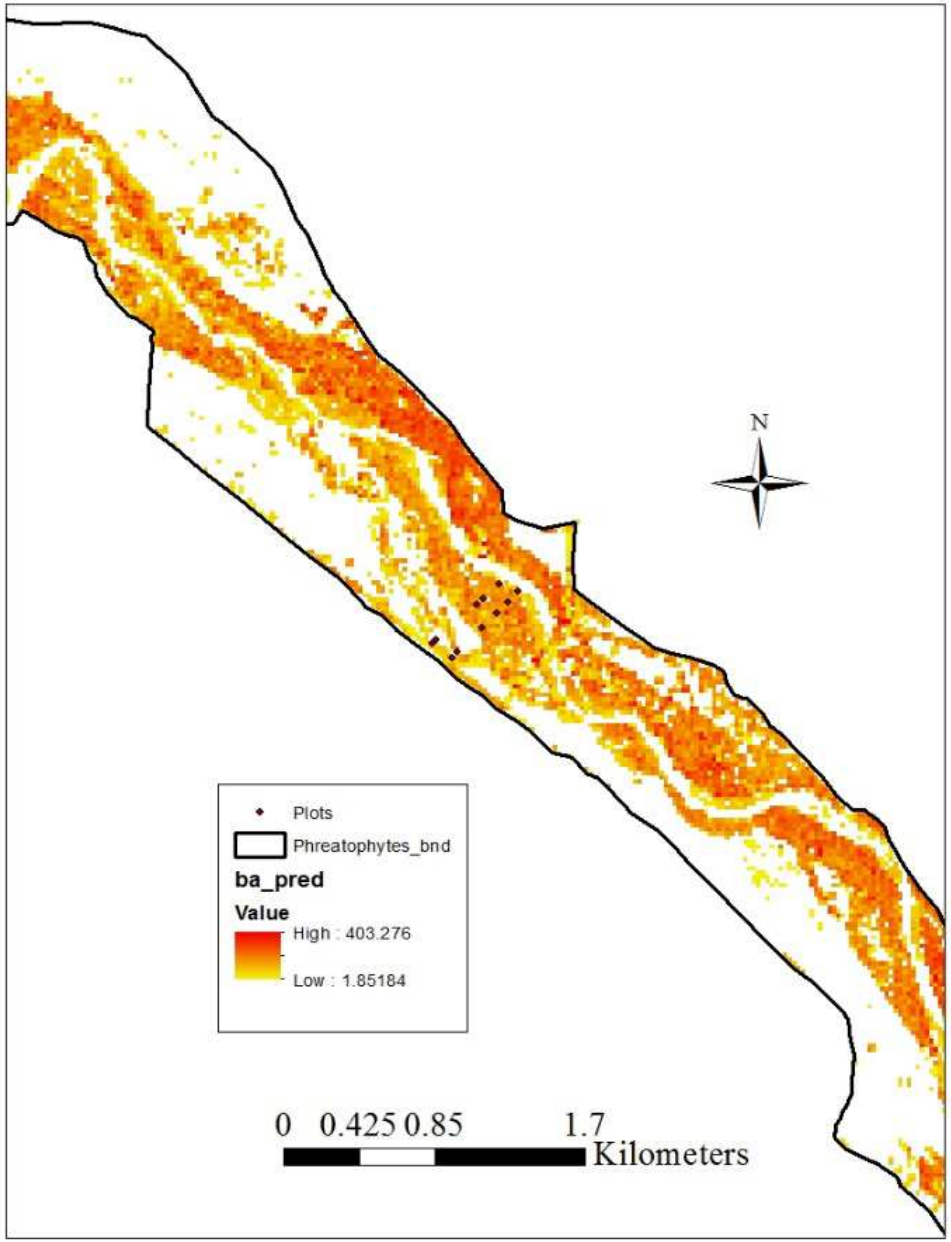

N
Plots
Phreatophytes_bnd
ba_pred
Value
High : 403.276
Low : 1.85184
0 0.425 0.85 1.7
Kilometers

Figure 5. Example of model output for predicted BA, site 11. The black squares labeled plots are along the surveyed transects.

Site	# plots	Hectare surveyed	American elm†	Box elder	Crack willow	Green ash†	Peach-leaf willow	Plains cottonwood	Russian olive*†	Siberian elm*†	Tamarisk *†	Other	Total	Total Non-native
1	46	9.2	0	0	0	0.20	1.38	10.83	1.57	0.07	0	0	14.05	1.84
2	24	4.8	0	0.26	0.52	0	0.08	2.87	0	0.12	0	0	3.86	0.13
3	67	13.4	0	0.08	0	0	0.72	16.21	0.93	0.26	0	0	18.19	1.19
4	48	9.6	0	0	0	0	2.52	4.87	0.66	0.01	0.01	0.02	8.09	0.68
5	47	9.4	0.01	1.75	0	0.02	2.84	12.87	0.02	0.74	0	0	18.24	0.79
6	47	9.4	0	0	0	0	0.83	10.81	0	0	0	0	11.64	0
7	59	11.8	0	0.19	0	0	3.71	12.35	0	0	0	0	16.25	0
8	48	9.6	0	0	1.46	0	1.05	2.49	0	0.75	0	0	5.76	0.75
9	65	13	0	0	0	0	2.26	8.84	0.02	0.14	0	0	11.25	0.16
10	63	12.7	0	0.24	0	0	0.94	21.44	0.62	0.20	0.01	0	23.45	0.83
11	112	22.4	0	0	0	0.58	1.57	14.30	0	0	0.04	0	16.49	0.62
12	46	9.3	0	0.07	0	0.27	0.61	12.80	0.21	0.14	0	0.02	14.12	0.62
13	61	12.2	0.02	0.20	0	1.63	0.05	8.11	0.33	0.19	0	0	10.53	2.17
14	84	16.86	0	0.09	0	0.82	2.16	15.55	0.12	0	0	0.05	18.79	0.94
15	56	11.2	0	0.03	0	0.60	3.68	15.73	0	0.69	0	0	20.74	1.29
Total	**873**	**174.86**	**0.03**	**2.91**	**1.98**	**4.12**	**24.41**	**170.07**	**4.48**	**3.31**	**0.07**	**0.09**	**211.46**	**12**
Percent of total, by species			**0.01**	**1.38**	**0.94**	**1.95**	**11.54**	**80.43**	**2.12**	**1.56**	**0.03**	**0.04**	**100.00**	**5.68**

Table 1. Summary of tree basal area (m^2) by species for each site. *Not native to North America †Not native to Colorado. Non-native column includes all species not native to Colorado.

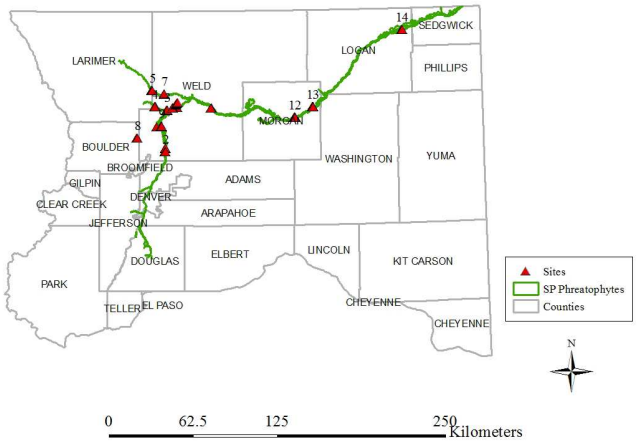
Site	# plots	Hectare surveyed	American elm†	Box elder	Crack willow	Green ash†	Peach-leaf willow	Plains cottonwood	Russian olive*†	Siberian elm*†	Tamarisk *†	Other	Total	Total Non-native
1	46	9.2	0	0	0	6	5	71	16	5	0	0	103	27
2	24	4.8	0	2	17	3	9	36	0	2	0	0	69	5
3	67	13.4	0	1	0	0	6	30	47	5	2	0	91	54
4	48	9.6	0	0	0	0	67	24	3	2	1	1	98	6
5	47	9.4	2	67	0	8	55	38	1	66	0	0	237	77
6	47	9.4	0	0	0	0	43	32	0	0	0	0	75	0
7	59	11.8	0	2	0	0	41	15	0	0	0	0	58	0
8	48	9.6	0	0	9	0	25	19	0	26	0	0	79	26
9	65	13	0	0	0	0	35	21	2	4	0	0	62	6
10	63	12.7	0	104	0	0	49	81	12	2	3	0	251	17
11	112	22.4	0	0	0	9	25	63	0	0	76	0	173	85
12	46	9.3	0	2	0	3	45	342	10	4	4	3	413	21
13	61	12.2	1	7	0	63	3	18	5	3	0	0	100	72
14	84	16.86	0	1	0	35	55	159	3	0	0	1	254	38
15	56	11.2	0	7	0	10	32	63	0	7	0	0	119	17
Total	**873**	**174.86**	**3**	**193**	**26**	**137**	**495**	**1012**	**99**	**126**	**86**	**5**	**2182**	**451**
Percent of total, by species			**0.14**	**8.85**	**1.19**	**6.28**	**22.69**	**46.38**	**4.54**	**5.77**	**3.94**	**0.23**	**100.00**	**20.67**

Table 2. Summary of number of individuals by site. *Not native to North America †Not native to Colorado. Non-native column includes all species not native to Colorado.

Site	# plots	Hectare surveyed	Japanese honeysuckle*	Golden currant	*Rosa* species	Sweetbriar rose	Wood's rose	Coyote willow	Snowberry	Total
1	46	9.2	2	13	0	0	86	228	2,856	3,185
2	24	4.8	0	314	0	0	0	10,728	483	11,524
3	67	13.4	34	0	0	0	0	0	40	74
4	48	9.6	0	0	0	0	0	241	0	241
5	47	9.4	1	0	1,545	0	0	705	0	2,253
6	47	9.4	0	0	0	0	0	7,238	0	7,238
7	59	11.8	0	25	0	155	0	8,946	2,005	11,131
8	48	9.6	0	7	0	0	0	4,247	4	4,258
9	65	13	0	0	0	0	6	2,334	0	2,340
10	63	12.7	0	88	0	175	87	13,028	74	13,452
11	112	22.4	0	0	109	1,339	5,566	100,626	26,010	133,655
12	46	9.3	0	247	0	0	10	17,189	2,746	20,192
13	61	12.2	0	97	37	8	45	36,593	4,251	41,034
14	84	16.86	0	0	0	19	15	50,078	2,910	53,023
15	56	11.2	0	20	0	98	76	331	1,845	2,370
Total	**873**	**174.86**	**37**	**811**	**1,691**	**1,794**	**5,891**	**252,509**	**43,223**	**305,968**
Percent of total, by species			**0.01**	**0.26**	**0.55**	**0.59**	**1.93**	**82.53**	**14.13**	**100.00**

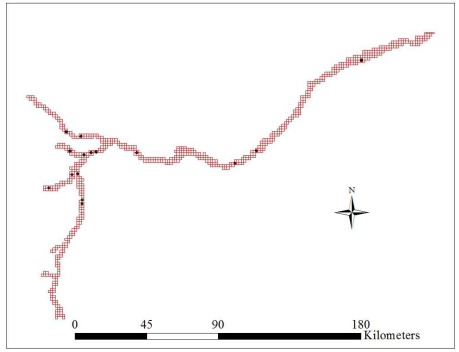
Table 3. Summary of shrubs recorded at 15 sites along the study area. Numbers are number of stems recorded per site. *Not native to North America.

Study Area



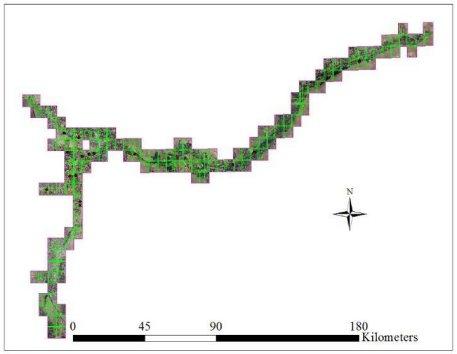
Acquiring Lidar Data

- Lidar data was acquired from FEMA (Federal Emergency Management Agency)
- Wednesday October, 16th 2013
- The whole study area is covered by 696 tiles that contain more than 8 billion cloud points
- Lidar data provide accurate information about heights and density



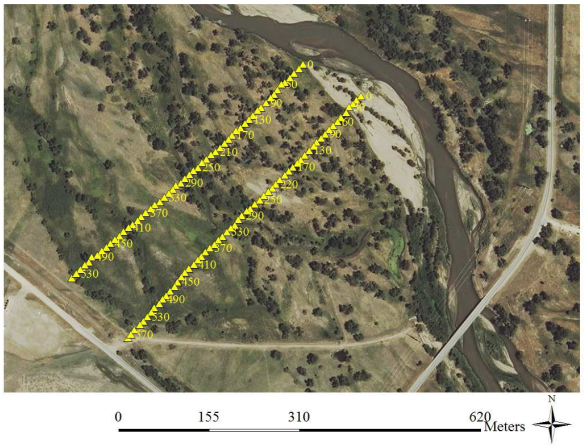
Acquiring Aerial Photos

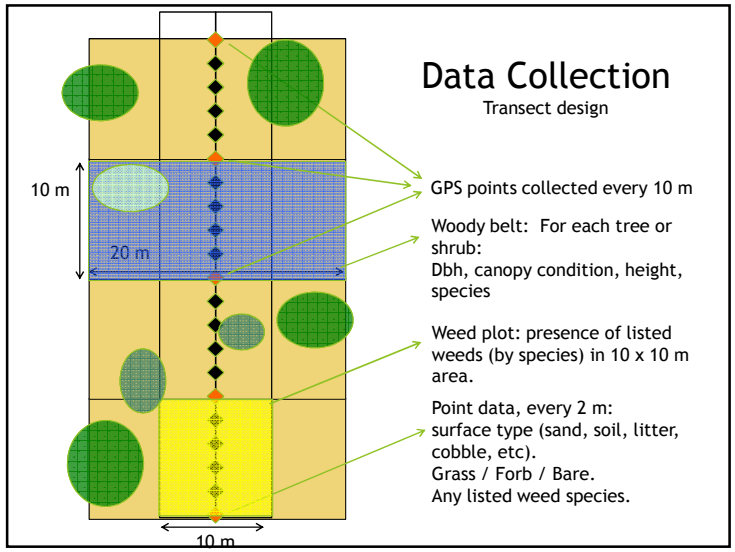
- Aerial Photos were acquired from USDA (United States Department of Agricultural)
- Tuesday, July 16th 2013
- 1 meter resolution and four bands (blue, green, red, and NIR)
- It provides useful information about vegetation and biomass



Transects perpendicular to river, across entire flood plain

Site 11





Data Collection

Transect design

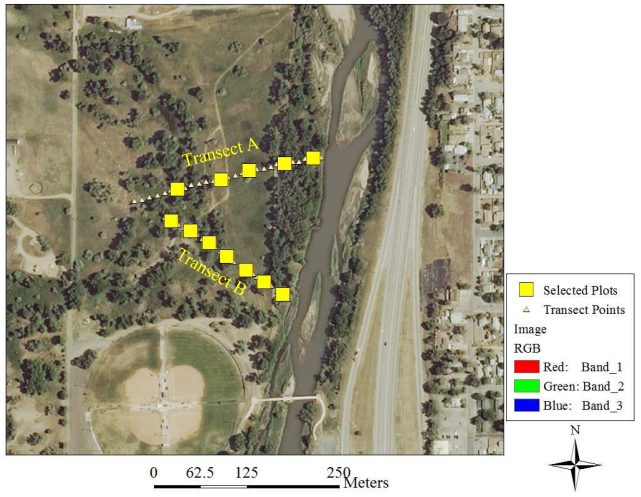
GPS points collected every 10 m

Woody belt: For each tree or shrub:
Dbh, canopy condition, height, species

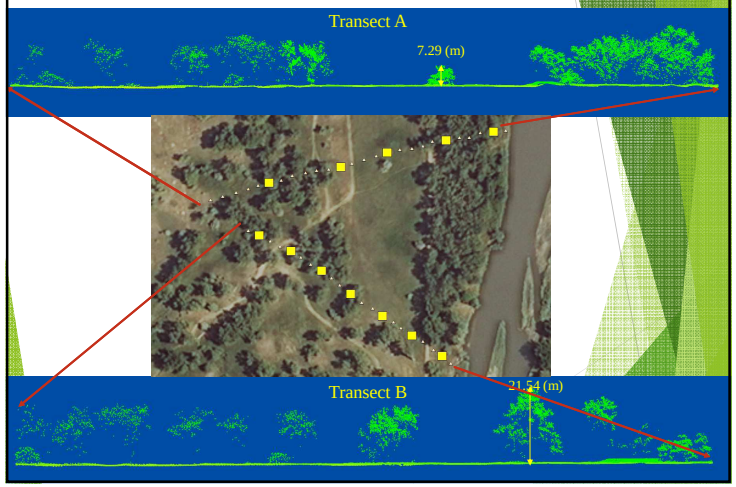
Weed plot: presence of listed weeds (by species) in 10 x 10 m area.

Point data, every 2 m:
surface type (sand, soil, litter, cobble, etc).
Grass / Forb / Bare.
Any listed weed species.

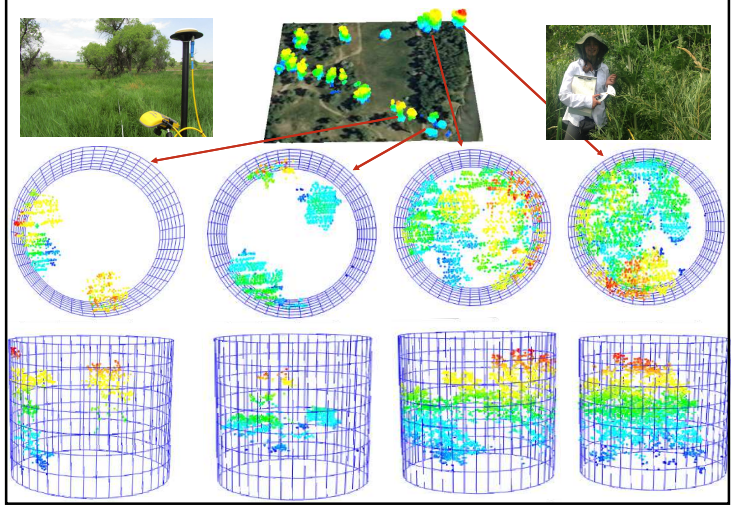
Transect data and Plot data

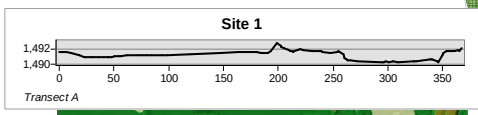


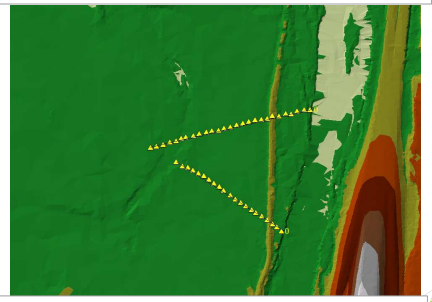
Tree profile (Site 1)

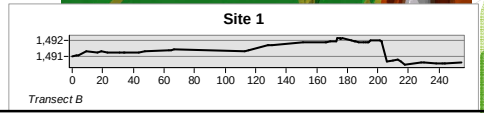


Visualizing Plots with Lidar data & aerial Phots (Site 1)









Outline of the forest inventory modeling process

- Forest inventory variables are measured in a sample of field plots
- Lidar metrics are calculated for each of the field plots
- Lidar technology measures the height and density characteristics of forest vegetation directly and consistently across large areas.
- Estimating and mapping forest inventory attributes such as biomass, basal area and timber volume across the landscape is possible because of statistical dependencies between lidar metrics and forest inventory variables measured on the ground (White et al 2013).
- Relationships between response variables measured in field plots and lidar predictor variables can be analyzed and described using statistical models.
- When statistical models are found that fit and predict response variables well, they can be applied across the landscape to make wall-to-wall predictions of forest inventory variables from the lidar data products (White et al 2013).

Applying Models across the landscape to create geospatial models of the forest inventory parameters.

- Direct Height Measurement:
  - 90th and 80th percentile height above ground of all returns above the 1 meter ground cutoff height
  - ElevP90 and ElevP80
- Density:
  - Percent Canopy Cover (# of 1st returns above 2m canopy threshold height / Total # of 1st returns)
- Height Distribution:
  - Standard deviation of the height above ground of all returns (STDEV)

Designate a Forest/Non-Forest Criteria

- All of the models were created from the relationship of forestry field plots and the associated lidar metrics.
- It is appropriate to apply the models to the forest portions of the of the study area.
- Designate a forest and non-forest criteria:
  - Each 20*20 meter pixel would need to contain vegetation of at least 3 meter in height and have at least 2% canopy cover.
- Apply Height Criteria
  - The p90 metric represents the 90th percentile heights. P90 is a good representation of each pixel averaged maximum, and amore stable measurement than the absolute maximum height of each pixel. This makes P90 a good metric to use for our criteria.
- Create an analysis mask to exclude non forest pixels from our model runs.

Developed Models

- Georeferenced Image:
  - It is a critical requirement for exploring LIDAR data in Fusion. It provides the coordinate system and visual reference for the LIDAR data
- Bare Earth Surface Model:
  - It provides the reference elevation for measuring the heights of features in the data.
  - It helps in measuring the heights of features above ground level not above sea level.
  - First we will filter the data to remove the above-ground LIDAR returns, then we will create the Bare Earth Surface from the remaining (ground) lidar returns.
  - Filter the data for bare earth points: This procedure is performed from the DOS command using the Groundfilter program. The algorithm that the executable is based on is described in: “Determination of terrain models in wooded areas with airborne laser scanner data” by K. Kraus and N. Pfeifer (1998, ISPRS).

Multiple Linear Regression

- $Yi = \beta i0 + \beta i1\ Xi,1 + \beta i2\ Xi,2 + \ldots + \beta ip\ Xi,p + \varepsilon i$ $\varepsilon i \sim N(0, \sigma 2)$
- Model Assumption:
  - The Y-values (errors, "e") are independent, data collection.
  - The Y-values can be expressed as a linear function of the X variable, resid. errors.
  - Variation of observation around the regression line (the residual SE) is constant (homoscedaticity), , resid. errors.
  - For a given value of X, Y values (the error) are normally distributed, , resid. errors.

Model Selection Schema

- Akaike's Information Criteria (AIC): A useful criterion for indicating the amount of information contained within variables, and deciding whether to omit certain variables. AIC draws its justification from Information Theory.
  - $AIC = 2p - 2\ln(L)$
    - where:
      - P is the number of coefficients being calculated, and L is the maximized value of the likelihood function for the model.
      - AIC effectively penalizes a model for using too many predictor variables, so we only include more predictor variables if they significantly increase the model's likelihood function. That is, only if they lend sufficient additional information to the model to justify their inclusion
- Coefficient of Determination (R^2): gives the amount of change in the y value explained by change in x value.
  - Adjusted Coefficient of Determination (R_a^2): Penalizes the Coefficient of Determination for the number of Predictors. Offers an alternative to AIC.
- Variance Inflation Factor: Quantifies the degree of multicollinearity in the model.

Outline of the forest inventory modeling process

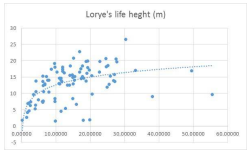
Data

Model

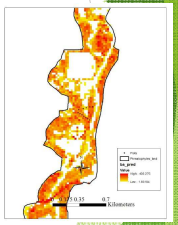
Prediction

Lidar plot metrics

BA = bo+nan

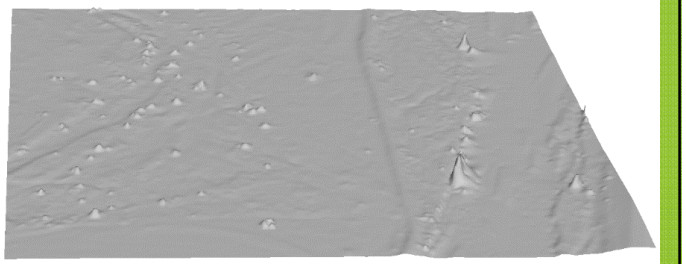


Model describing relationship between the lidar plot metrics and field plot measurements

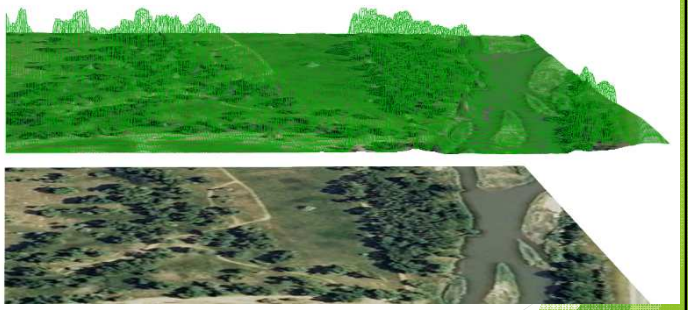


Field plot measurements

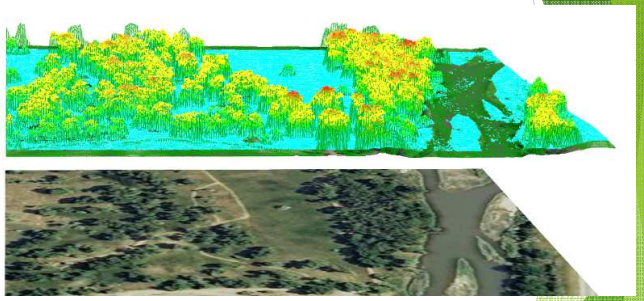
Bare Earth profile (Site 1)



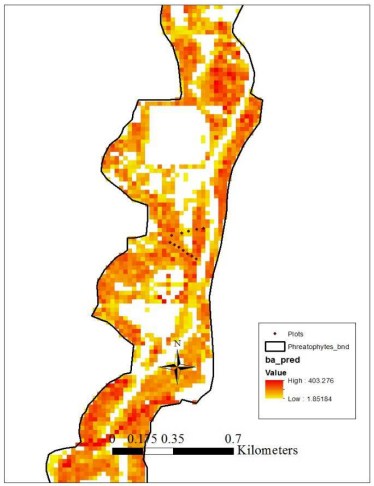
Canopy Surface Model (Site 1)



Canopy Surface Model (Site 1)

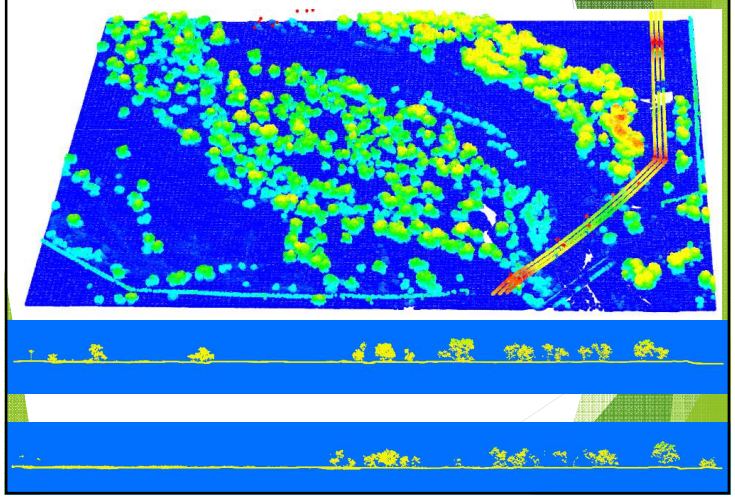


Predicted Basal Area (S1)

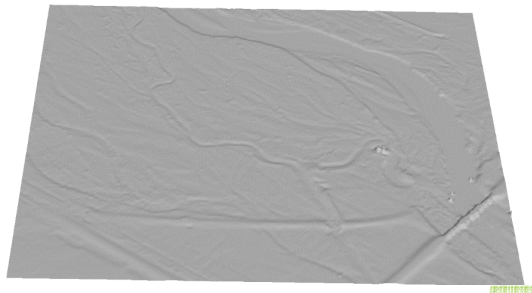


Transect (Site 11)

Tree Profile (Site 11)

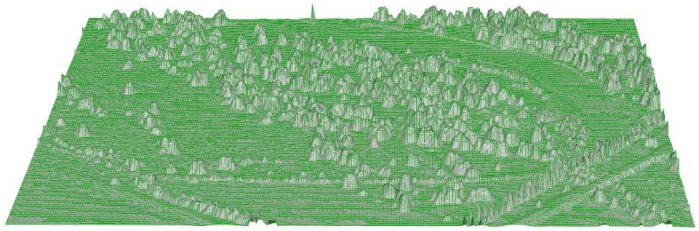


Bare Earth Surface Model (Site 1)

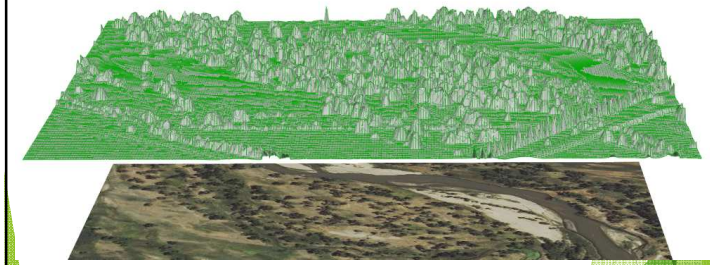


Bare Earth Surface Model (Site 1)

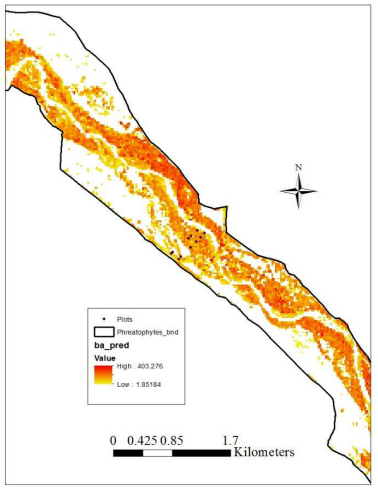
Canopy Surface Model (Site 1)

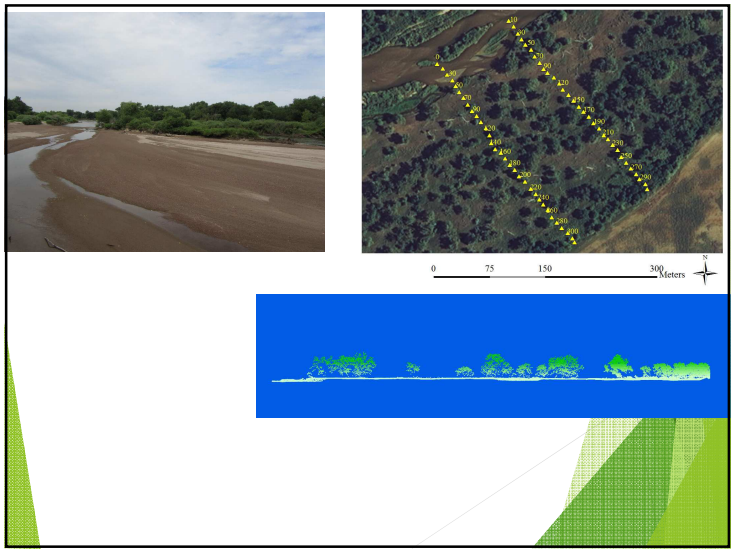


Canopy Surface Model (Site 1)

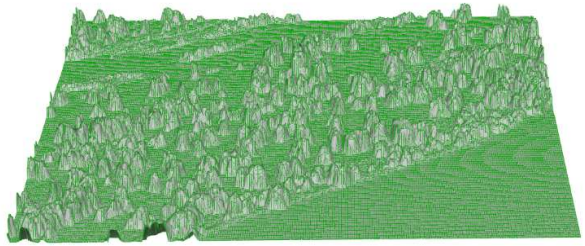


Predicted Basal Area (S11)

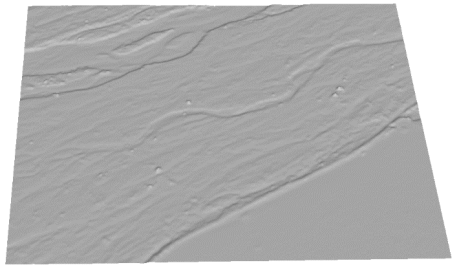




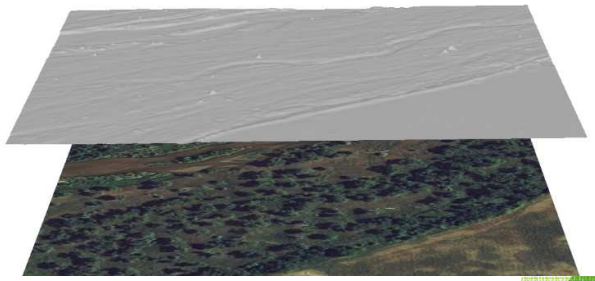
S13



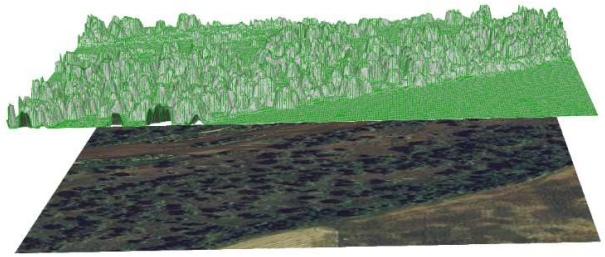
S13



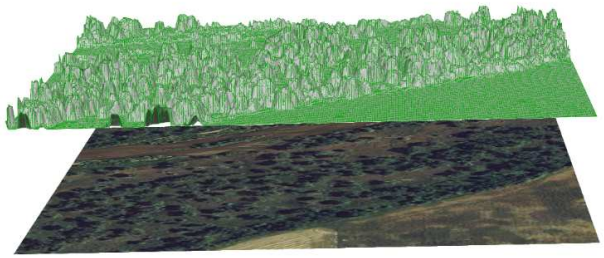
S13



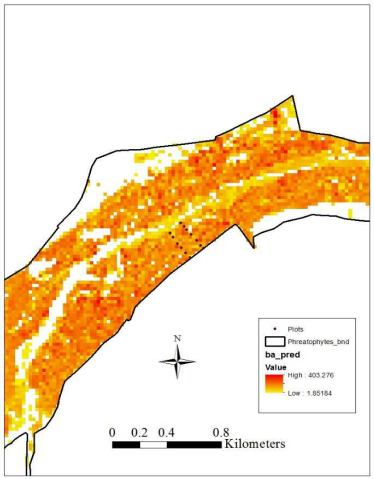
S13



S13



Predicted Basal Area (S13)



South Platte Phreatophyte Survey

Update February 8 2016

Background

In 2013, following a few days of intense rainfall, The Poudre, Big Thompson, St. Vrain rivers and Boulder Creek experienced record flooding.

Goal: Assess current situation, look for evidence of recent change in abundance or recruitment so that we can develop appropriate management plans.

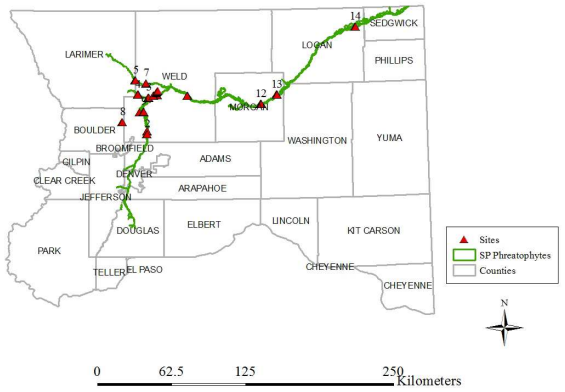
Possible effects of floods:

* Increased recruitment due to more available water, flood disturbance.

* Increased growth, due to more water and lower groundwater depth (though this would be temporary).

* Reduced phreatophyte abundance due to flood-induced mortality.

Study Area



Approach

- Field surveys of woody vegetation along transects perpendicular to river, within the flood plain.
- Field surveys of listed weeds along these transects.
  - *Assumption: Mitigation costs* for noxious weeds following phreatophyte removal often exceeds direct cost of removal. Mitigation costs are a function of what is present pre-removal disturbance.*
- Remote sensing data and analysis.
- Combine these data to model abundance patterns through space and time.

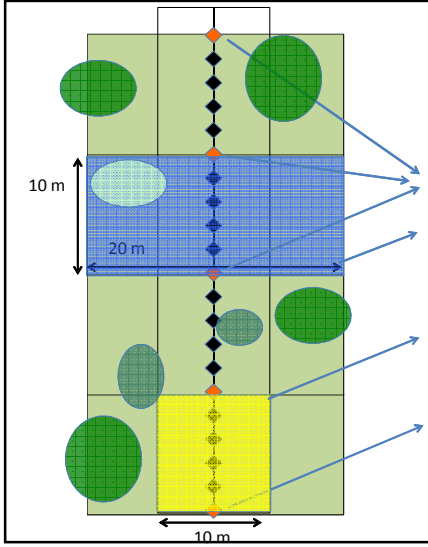
- *costs include herbicide and application costs, active re-vegetation if needed.

Transects perpendicular to river, across entire remaining flood plain

Site 11

Data Collection

Transect design



GPS points collected every 10 m

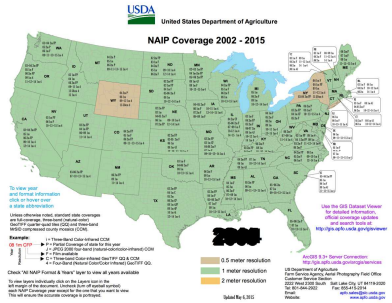
Woody belt: For each tree or shrub:
Dbh, canopy condition, height, species

Weed plot: presence of listed weeds (by species) in 10 x 10 m area.

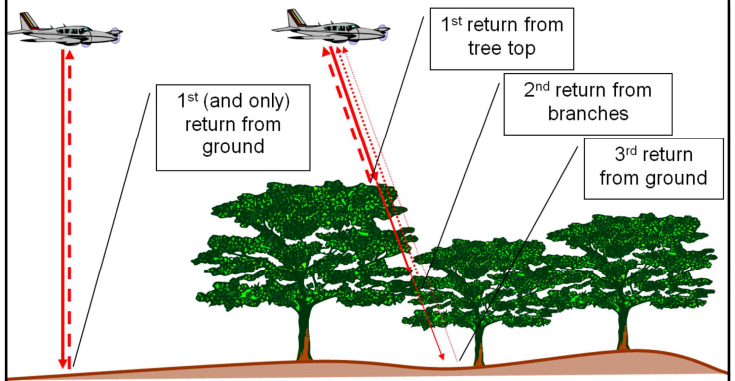
Point data, every 2 m:
surface type (sand, soil, litter, cobble, etc).
Grass / Forb / Bare.
Any listed weed species.

Data Collection – remote sensing data

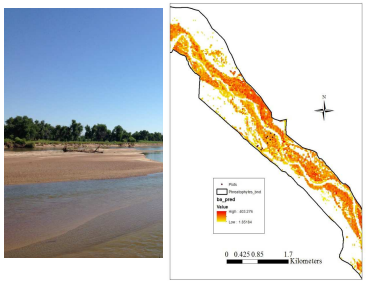
- Aerial imagery USDA-NAIP data: 4 band 1 m resolution in 2009, 2011, 2013 and 2015 (soon).
- LiDAR (Light Detection and Ranging): 2013! immediately after the flood!, 2015 (maybe)?

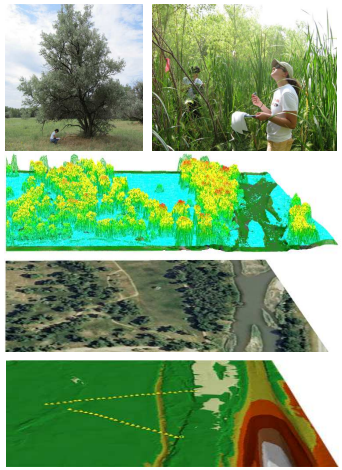


LiDAR – high spatial resolution (10 cm or so), precision elevation data. No information on color.



Approach





Flood impacts on invasive plants along the South Platte River

Work flow

1) Use LiDAR and woody data to create a predictive model of tree and shrub biomass for the entire study area.
-> Maps biomass / dbh for entire study area.

2) Add in 2015 aerial imagery to predict biomass by species or species groups, and partition area into habitat types (woodland, shrub, grassland, etc.).
-> Partitions the above by species or species groups.

3) Use historical imagery (2013 or earlier) along with current map to estimate pre-flood conditions.

4) Compare state pre- to post-flood.

Current state

Refined map of current state

Estimate of historic state

Change post-flood

Preliminary observations

8.7 km of transects
873 plots = 75 ha = 432 acres.

A) Lots of weeds.
- A) Cheatgrass > 8% cover
- B) Whitetop > 4% cover
- C) Lots of new(ish) weeds: Cut-leaf teasel is common. Moth mullein is more common than I expected.

Preliminary observations

A) Much more recruitment from cottonwood than I expected.

B) Little recruitment from Russian olive.

C) Flood induced mortality is common

Mapping Phreatophytes inventory parameters of the South Platte River Basin

PART 1: Using Lidar Data

Overview

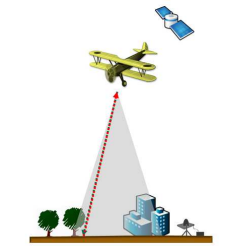
- Mapping Phreatophytes inventory parameters of the South Platte River Basin is divided into three stages:
  1. **Using Lidar Data**
  2. **Using Aerial Images:**
  3. **Integration of Lidar and Aerial images**
  4. **Investigated the impact of 2013 flood using Lidar and Aerial Images**

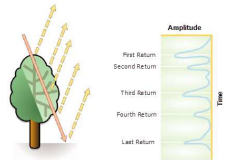
Part 1: Using Lidar Data

- **Develop beneficiary models of the South Platte Basin area such as:**
  - **Bare Earth Model (BE).**
  - **Canopy Surface Model (CSM).**
  - **Canopy Height Model (CHM).**
  - **Vegetation Density.**
- **Mapping and quantifying the Basal Area (BA) of Phreatophytes of the South Platte River Basin.**
- **Mapping and quantifying different tree species over the whole area.**

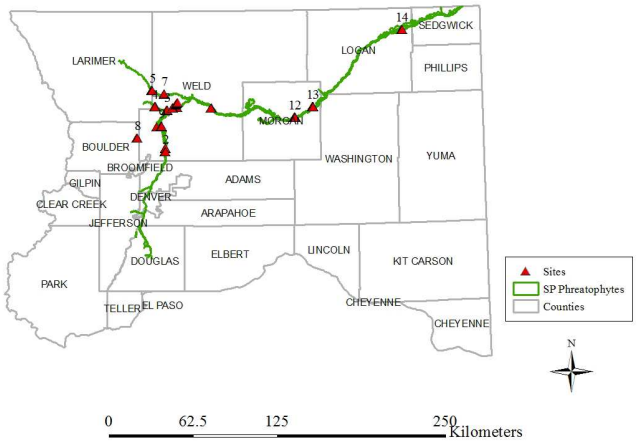
LiDAR DATA

- Lidar (Light Detection and Ranging): is a remote sensing technology that uses light in the form of a pulsed laser to measure variable distances to the Earth.
- LAS files is an industry-standard binary format for storing LiDAR data.
- A LAS dataset stores reference to LAS files on disk, as well as to additional surface features.
- A LAS file contains liDAR point cloud data.



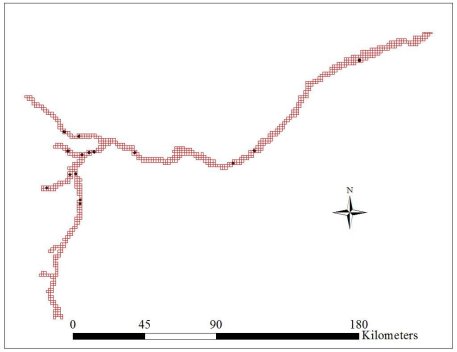


Study Area



Acquiring Lidar Data

- Lidar data was acquired from FEMA (Federal Emergency Management Agency)
- Wednesday October, 16th 2013
- The whole study area is covered by 696 tiles that contain more than 8 billion cloud points
- Lidar data provide accurate information about heights and density



Lidar data and Field Data

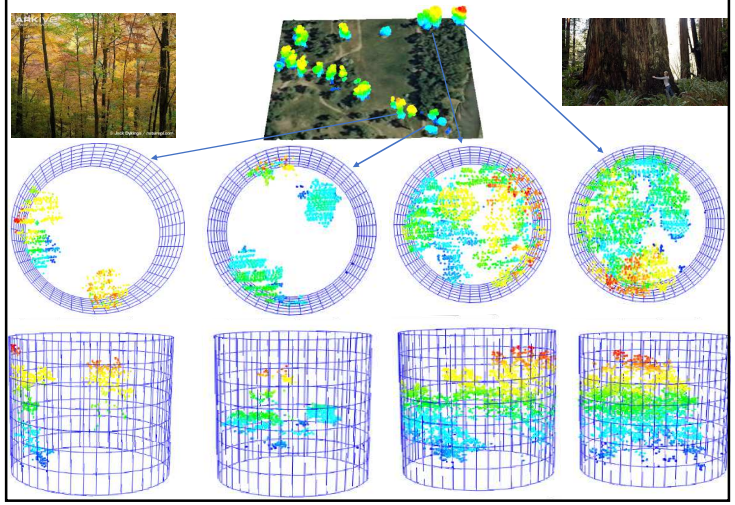
- From Lidar data alone, maps with 0.5 meter resolution can be developed for the following:
  - Digital Elevation Model (DEM)
  - Digital Surface Model (DSM)
  - Digital Height Model (DHM)
  - Normalized Digital Surface Model (NDSM)
  - Vegetation Model
  - Canopy closure.
  - Relative vegetation density for a specific height.
- Lidar with field data, predicted maps with 20 meter resolution can be developed for the following:
  - Basal Area
  - Tree Species

Collecting field data for Lidar Regression

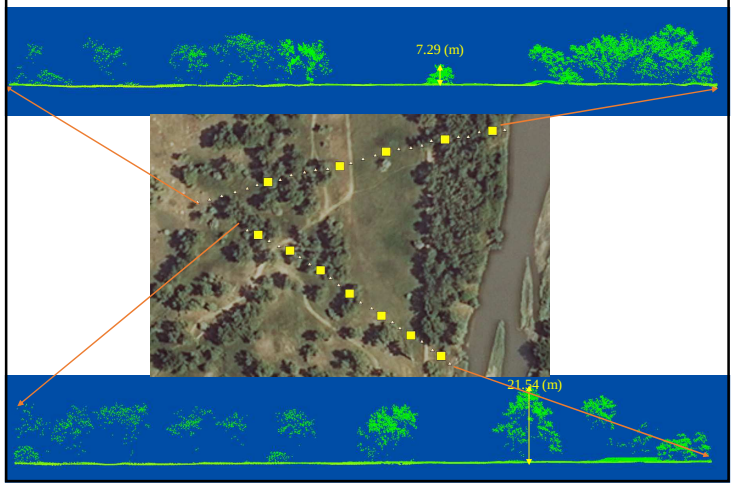
- In order to get better results from Lidar data, collected field samples should be:
  - Stratified samples where everything in the sample plot should be measured.
  - Plot size should not be less than 0.1 acre ` 20m*20m
  - Each individual plot should contain only one species, for better classification of trees.
  - At least DBH (depth at breadth height) and height of each individual tree should be measured
- For this study, 103 plots were collected.
- The Lidar data are clipped over the areas of the plots to generate Lidar matrix.
- The Lidar matrix contains all possible statistics of the Lidar data (Height and Intensity) for the plots such as: max., min., mean, mode, stdev, cv, variance, all percentiles, etc.
- A regression model is developed to establish a relationship between plots data (field data) and Lidar matrix.
- If the developed model shows a satisfactory results ($r^2 > 0.6$), the model is applied over the whole study area for regression develop Basal Area or Classification to develop trees species classifications.

Sampling Design

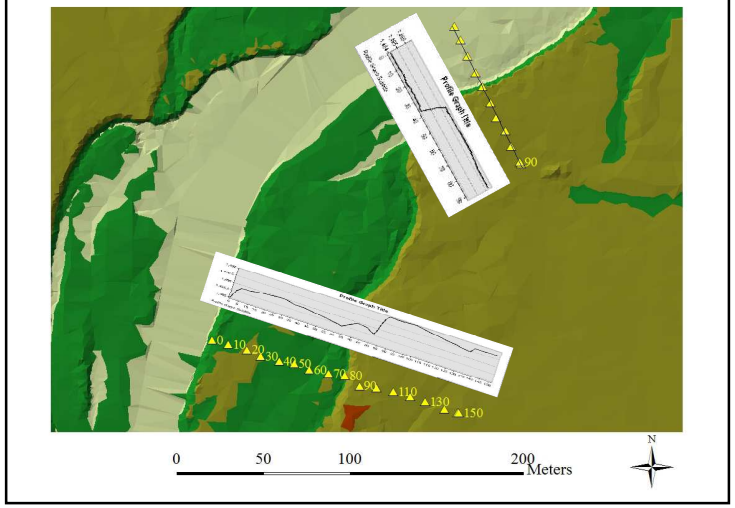
Visualizing Plots with Lidar data & aerial Phots



Transects Profiles of Trees

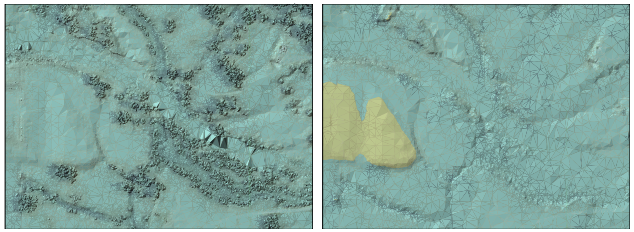


Bare Earth



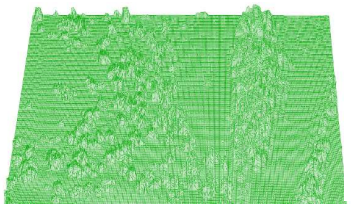
Canopy Surface and Bare Earth Models

- Canopy Surface Model
- Digital Elevation Model

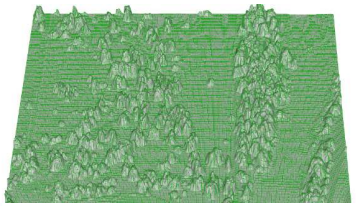


Canopy Models

Canopy Height Model



Canopy Surface Model



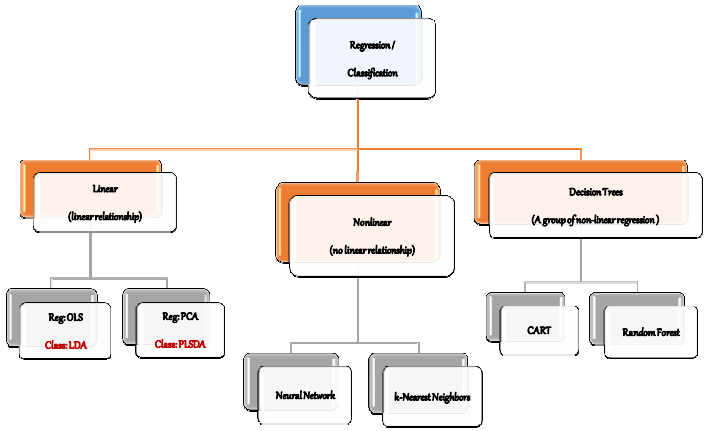
Regression/Classification Models

- Forest inventory parameters are modeled by building regression/classification models between forest inventory parameters measured on field plots and their associated lidar canopy metrics.
- Inventory parameters that could be successfully modeled will be calculated for the full extent of the lidar data.
- The resulting models will be applied to the lidar data resulting in continuous GIS raster layers of the forest inventory parameters across the study area.

Regression / Classification Models

- Linear:
  - Regression:
    - Ordinary Least Squares (OLS):
      - It minimizes the sum of the squared errors.
    - Principal Component Regression (PCR):
      - It is useful when the data has highly- correlated predictors.
  - Classification:
    - Linear Discriminant Analysis (LDA):
      - It finds a linear combination of data attributes that best separate the data into classes.
    - Partial Least Squares Discriminant Analysis (PLSDA):
      - It is the application of LDA that -reduces partial least squares.
- Non-linear (Regression / Classification)
  - Multivariate Adaptive Regression Splines (MARS):
    - It is a non-parametric regression method that models multiple nonlinearities in data using hinge functions (functions with a kink in them)
  - k-Nearest Neighbor:
    - It creates predictions from close data. A similarity measure such as Euclidean distance is used to locate close data in order to make predictions.
  - Neural Network :
    - Is is a graph of computational units that receive inputs and transfer the result into an output that is passed on. The units are ordered into layers to connect the features of an input vector to the features of an output vector. With training, neural networks can be designed and trained to model the underlying relationship in data.
- Decision Tree (Regression / Classification)
  - Classification and Regression Trees (CART):
    - It splits the attributes based on values that minimize sum of squared errors.
  - Random Forest:
    - It is an ensemble learning method for regression/classification, that operate by constructing a multitude of decision trees at training time and outputting the class that is the mode of the classes (classification) or mean prediction (regression) of the individual trees. Random forests correct for decision trees' habit of overfitting to their training set

Regression/Classification Models

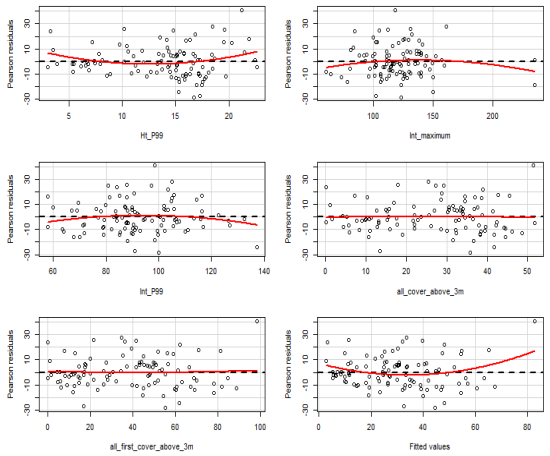


Linear Regression

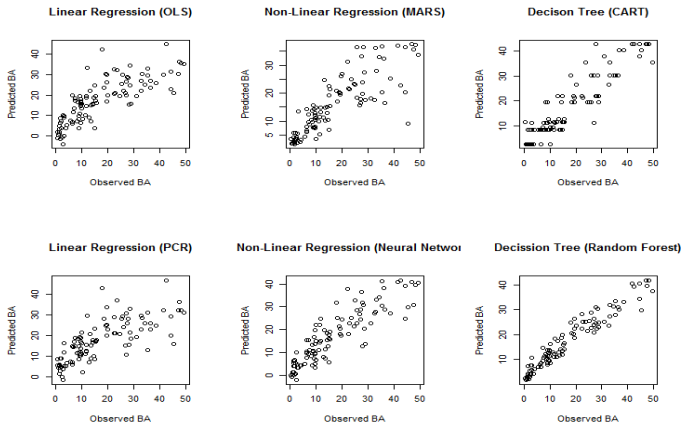
Using Stepwise to Selected the best correlated variables

```
Residuals:
     Min       1Q   Median       3Q      Max
-24.4724  -5.4999  -0.6597   3.7908  24.4748

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)       84.659313  19.061971   4.441 2.39e-05 ***
Elev_maximum       2.771434   0.760896   3.642 0.000438 ***
Elev_mode         -2.840989   0.760235  -3.737 0.000316 ***
Elev_stddev       -4.846106   2.348184  -2.064 0.041738 *
Canopy_relief_ratio 97.467399 21.384803   4.558 1.52e-05 ***
Int_stddev        -1.004336   0.298432  -3.365 0.001100 **
Int_variance       0.008213   0.002862   2.869 0.005061 **
Int_P99            0.091674   0.047595   1.926 0.057045 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 8.472 on 96 degrees of freedom
Multiple R-squared:  0.6296,   Adjusted R-squared:  0.6026
F-statistic: 23.31 on 7 and 96 DF,  p-value: < 2.2e-16
```

Residuals of Linear Regression



Results Using Different Regression Models



Results Using Different Classification Models

Linear Discriminant Analysis (LDA)

lda_predictions	ACENEG	ELAANG	POPDEL	SALAMY	SALEXI
ACENEG	2	0	0	1	0
ELAANG	0	2	1	2	0
POPDEL	0	1	65	2	0
SALAMY	2	4	1	11	0
SALEXI	0	0	0	0	10

Partial Least Squares Discriminant Analysis (PLSDA)

plsda_predictions	ACENEG	ELAANG	POPDEL	SALAMY	SALEXI
ACENEG	0	0	2	3	0
ELAANG	3	7	5	1	1
POPDEL	1	0	58	3	0
SALAMY	0	0	2	8	0
SALEXI	0	0	0	1	9

k-Nearest Neighbor

knn_predictions	ACENEG	ELAANG	POPDEL	SALAMY	SALEXI
ACENEG	0	0	0	0	0
ELAANG	1	5	1	0	0
POPDEL	3	1	64	10	3
SALAMY	0	0	1	5	1
SALEXI	0	1	1	1	6

Neural Network

nn_predictions	ACENEG	ELAANG	POPDEL	SALAMY	SALEXI
ELAANG	3	6	0	0	0
POPDEL	0	1	67	2	1
SALAMY	1	0	0	14	0
SALEXI	0	0	0	0	9

Classification and Regression Trees (CART)

cart_predictions	ACENEG	ELAANG	POPDEL	SALAMY	SALEXI
ACENEG	0	0	2	3	0
ELAANG	3	7	5	1	1
POPDEL	1	0	58	3	0
SALAMY	0	0	2	8	0
SALEXI	0	0	0	1	9

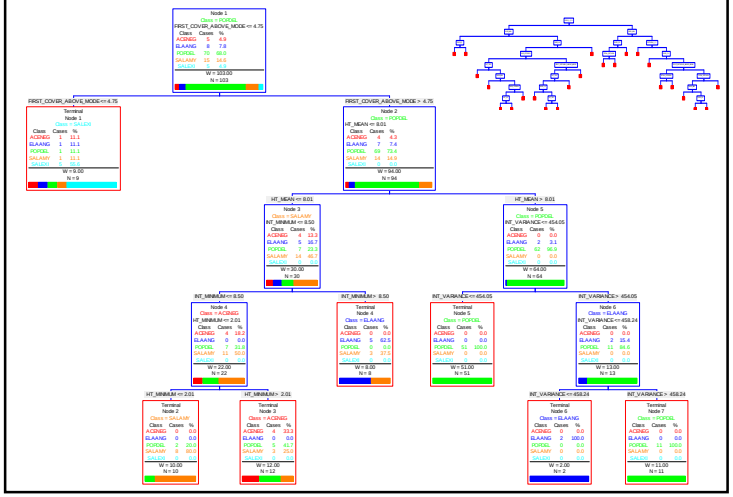
Random Forest

rf_predictions	ACENEG	ELAANG	POPDEL	SALAMY	SALEXI
ACENEG	4	0	0	0	0
ELAANG	0	7	0	0	0
POPDEL	0	0	67	0	0
SALAMY	0	0	0	16	0
SALEXI	0	0	0	0	10

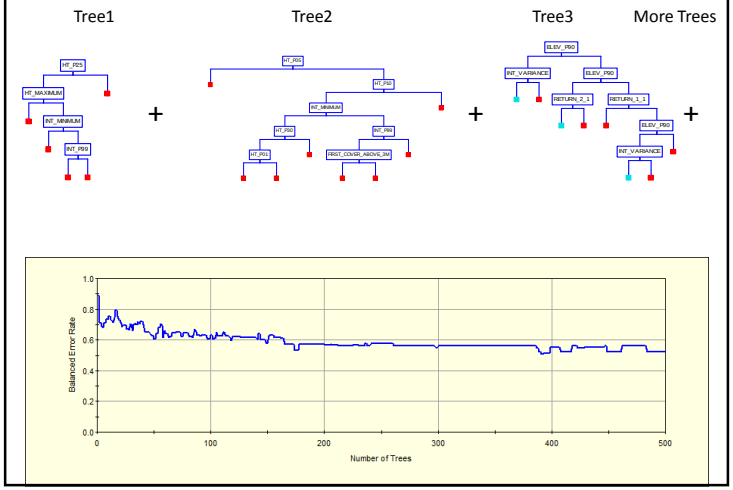
Selecting the Best Model

- The pervious investigation of different models shows that the best model is the random forest.
- It is an ensemble learning method for regression/classification, that operate by constructing a multitude of decision trees at training time and outputting the class that is the mode of the classes (classification) or mean prediction (regression) of the individual trees
- Random forests correct for decision trees' habit of overfitting to their training set
- The developed model of random forest in the following example uses around different independent trees.
- The model is used to develop inventory parameters of the whole study area such as Basal Area
- Advantages of Random Forest:
  - Built-in estimates of accuracy no need for validation)
  - Automatic variable selection
  - Variable importance
  - Works well "off the shelf"
  - Handles wide data

Classification Tree

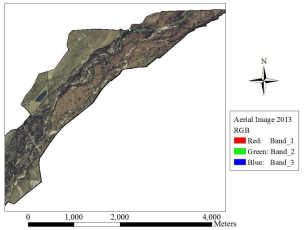


Random Forest Model

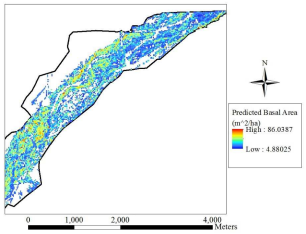


Example 1: Predicted Basal Area & Tree Species

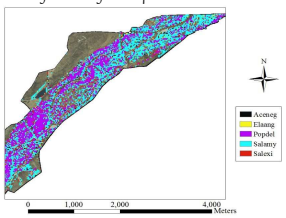
The Aerial Image

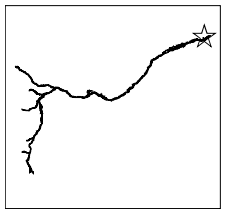


Predicted Basal Area (m^2/ha)



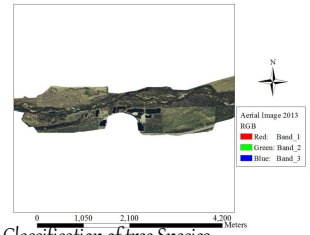
Classification of tree Species



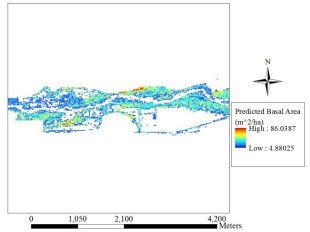


Example 2: Predicted Basal Area & Tree Species

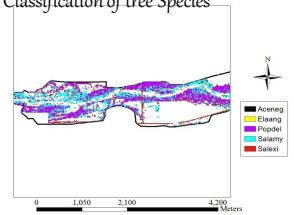
The Aerial Image

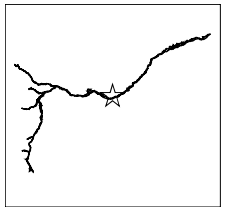


Predicted Basal Area (m^2/ha)



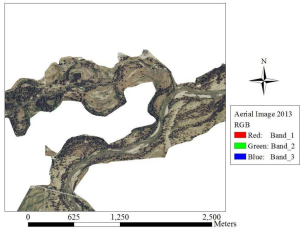
Classification of tree Species



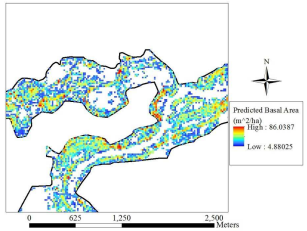


Example 3: Predicted Basal Area & Tree Species

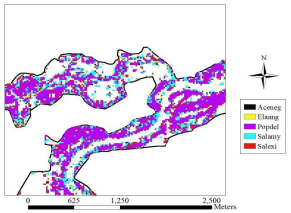
The Aerial Image

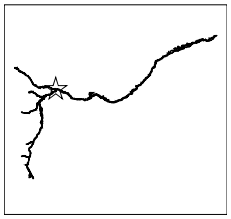


Predicted Basal Area (m^2/ha)



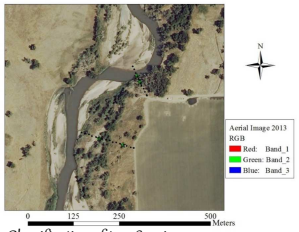
Classification of tree Species



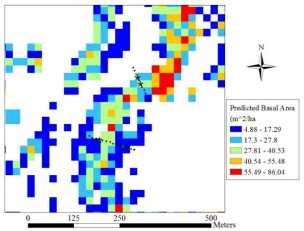


Site 2: Predicted Basal Area Using Lidar Data

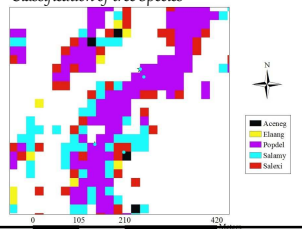
The Aerial Image

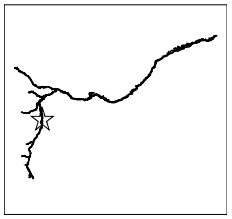


Predicted Basal Area (m^2/ha)



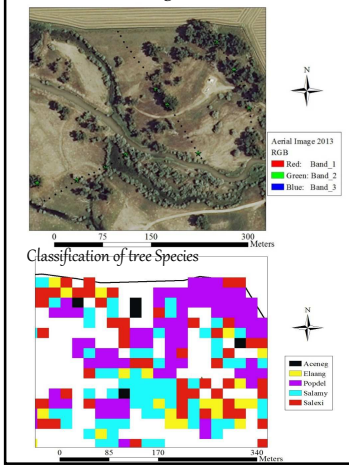
Classification of tree Species



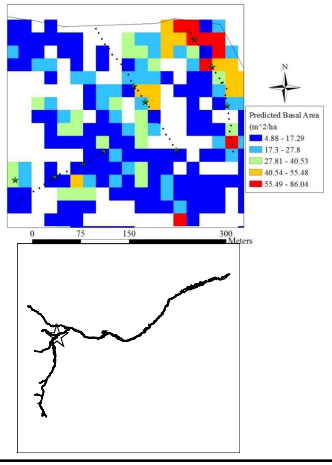


Site 3: Predicted Basal Area Using Lidar Data

The Aerial Image



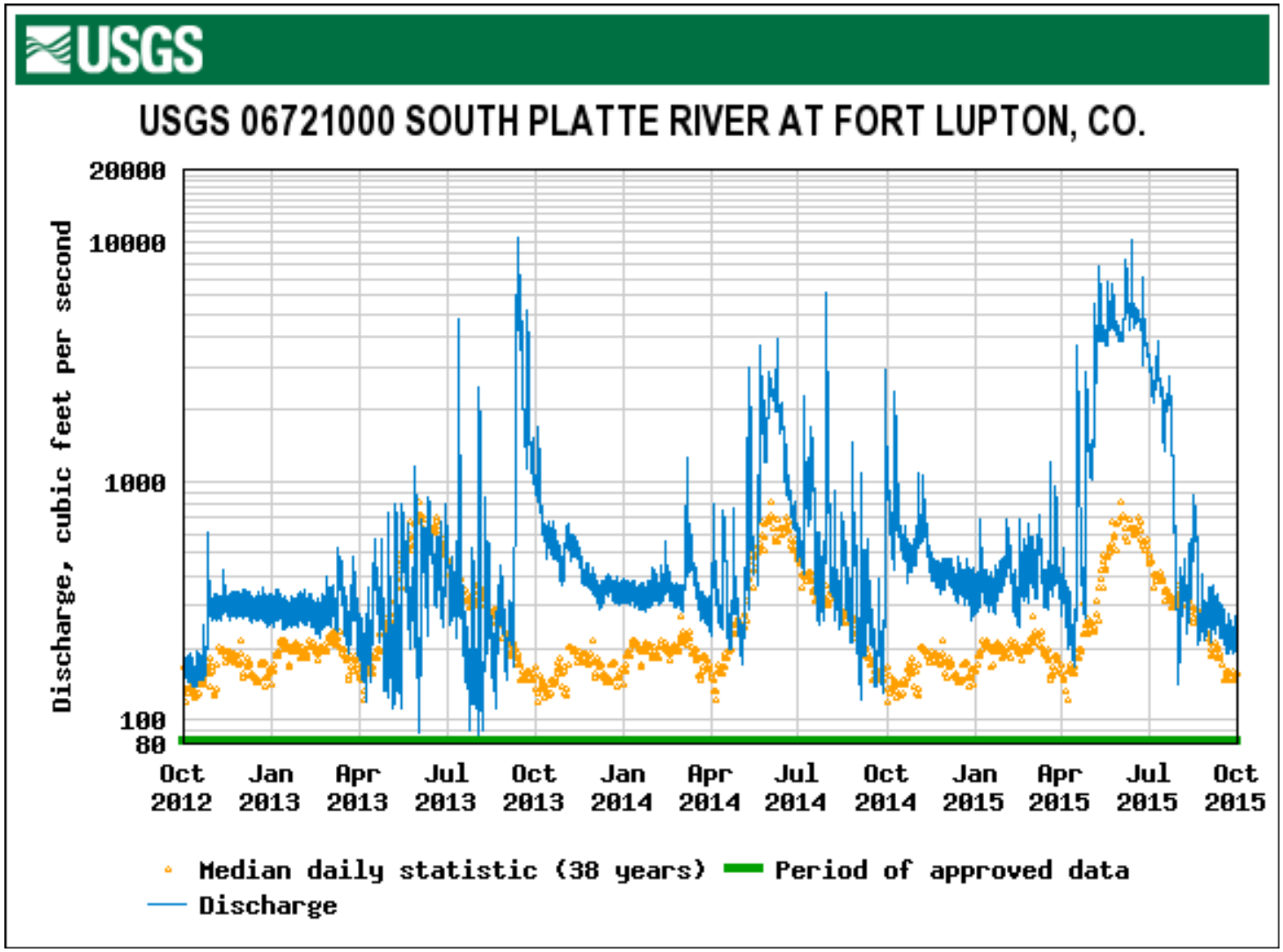
Predicted Basal Area (m^2/ha)

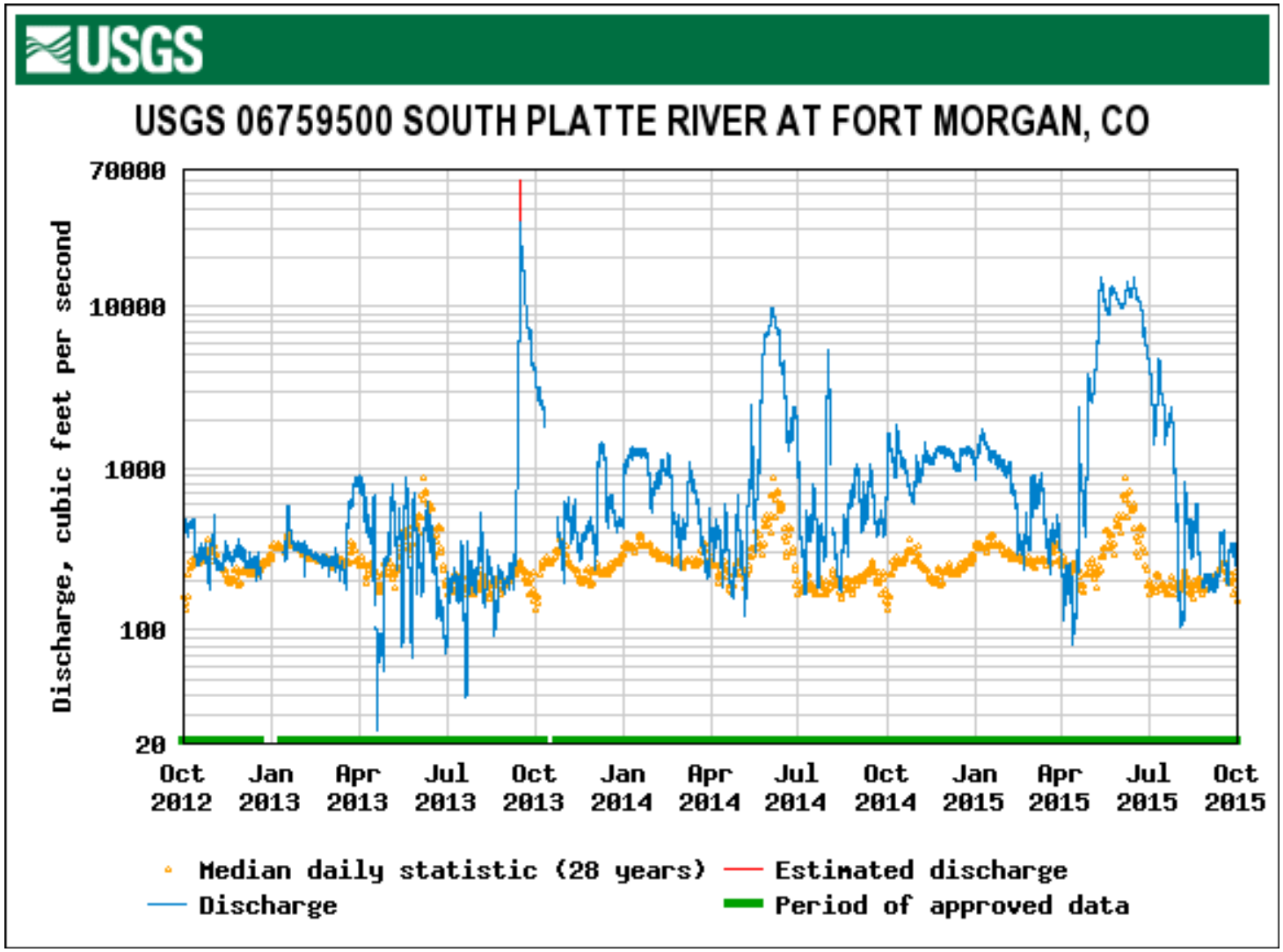


Classification of tree Species

Important Notes

- More plot samples are needed during summer to improve the classification and regression and to validate the models.
- The previous procedure will be applied to the aerial Images (different bands and different vegetation indices).
- The final maps will be an integration of Lidar and aerial images.


USGS
USGS 06721000 SOUTH PLATTE RIVER AT FORT LUPTON, CO.
Discharge, cubic feet per second
20000
10000
1000
100
80
Oct 2012
Jan 2013
Apr 2013
Jul 2013
Oct 2013
Jan 2014
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015
Median daily statistic (38 years)
Period of approved data
Discharge


USGS
USGS 06759500 SOUTH PLATTE RIVER AT FORT MORGAN, CO
Discharge, cubic feet per second
70000
10000
1000
100
20
Oct 2012
Jan 2013
Apr 2013
Jul 2013
Oct 2013
Jan 2014
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015
Median daily statistic (28 years)
Estimated discharge
Discharge
Period of approved data

Progress Report to the Colorado General Assembly On the SB 14-195 South Platte Phreatophyte Study

("A study to evaluate the growth and identification of phreatophytes along the South Platte River in the aftermath of the September 2013 flood")

DRAFT MARCH 16, 2016

DRAFT

Submitted by the Colorado Water Conservation Board
April 2016

CONTENTS

ATTACHMENTS

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1. INTRODUCTION

SB 14-195, signed by Governor Hickenlooper on June 6, 2014, directs the Colorado Water Conservation Board ("Board") to:

> "*conduct at least the preliminary stages of a comprehensive study to evaluate the growth and identification of phreatophytes along the South Platte River in the aftermath of the September 2013 flood*".

Additionally, the bill directs that:

> "*the Board shall prepare a progress report and present it to a joint meeting of the House of Representatives Committee on Agriculture, Livestock, and Natural Resources and the Senate Committee on Agriculture, Natural Resources, and Energy, or their successor committees, during the second regular session of the Seventieth General Assembly in 2016*".

Finally the bill requires that:

> "the Board shall prepare a Final Report, including its conclusions, and present it to the General Assembly no later than December 31, 2016".

The following report documents the Board's study efforts through December 2015 and its plan to provide the Final Report to the General Assembly by December 31, 2016.

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2. SB14-195 REQUIREMENTS

SB14-195 amended CRS 37-60-115 by adding a new subsection 9 directing the Board to "*conduct at least the preliminary stages of a comprehensive study to evaluate the growth and identification of phreatophytes along the South Platte River in the aftermath of the September 2013 flood*"

The bill contained several specific objectives for the study to address:

- "evaluate the growth and identification of phreatophytes … in the aftermath of the September 2013 flood"
- "determine the relationship between high groundwater and non-beneficial consumptive use by phreatophytes"
- "develop a cost analysis for the removal of unwanted phreatophytes"

No additional funds were appropriated to the CWCB for the study. Instead the Board was authorized to use existing funds, previously allocated to its phreatophyte control grant program ("the Grant Program"). While the bill authorized the Board to "accept and expend gifts, grants, and donations for the purposes" of the study, no such funds were sought or received by the Board for the study. In June 2014, when SB-195 was enacted, the unencumbered balance in the Grant Program was approximately $280,000, of which $100,000 had been committed to control projects in the final stages of development.

The bill suggests that the Board utilize Colorado State University's Bioagricultural Sciences and Pest Management Program (CSU) to conduct the study. It further directs that the Board coordinate with the Colorado Department of Agriculture and weed management specialists from local governments.

As described below each of these elements were incorporated into the study process and development of the study approach and final Scopes of Work (SOW). The full text of SB14-195 is included in the Attachments section of this report.

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3. INTERACTIONS WITH SOUTH PLATTE BASIN ROUND TABLE (BRT) and OTHERS

Beginning in May 2014, the Board staff initiated discussions with CSU on their interest and ability to conduct portions of the study in anticipation of SB-195 being enacted. These discussions also included the Colorado Water Institute (CWI) based on the Institute's extensive recent work on South Platte groundwater issues pursuant to other earlier legislation, which had also included some analysis of phreatophyte issues in the basin.

After it was confirmed that CSU was able and available to work on the project, a series of outreach meetings were held in the basin. These meetings were convened through the Phreatophyte Subcommittee (Subcommittee) of the South Platte BRT. The initial meetings focused on explaining the requirements of SB-195 and obtaining feedback on the phreatophyte issue in general and impressions on how the 2013 flood impacted that issue. One issue that quickly surfaced was whether to focus on all phreatophytes or just the non-native varieties, recognizing that both native and non-natives consume similar amounts of water. It was recommended to measure the prevalence of all species, but not assume that all types could or should be controlled. Instead watershed health and appropriately functioning riparian areas was a goal that received general support. Input was also obtained on the appropriate geographic area for the study as described below.

Based on input from these initial meetings, the requirements of SB-195 itself, and the expertise of CSU's researchers and the CWI a two phase plan of study and Scopes of Work (SOW) were developed. In subsequent meetings with the Subcommittee the SOWs were revised and eventually finalized. A total of four meetings with the Subcommittee or BRT were held. A timeline is included later in this report. In addition, the final draft SOW was provided to, and comments received from, the State Weed Manager in the Colorado Department of Agriculture and the Weld County Weed Supervisor.

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4. DEVELOPMENT OF SCOPE OF WORK FOR THE STUDY

Based on previous experience and general knowledge of South Platte basin, flood hydrology, and phreatophyte ecology, the Board's staff developed several hypotheses concerning the likely impacts of the 2103 flood on the issues identified in SB14-195.

- In general, groundwater table elevation changes, or bank storage, due river stage increase during the flood event were likely of brief duration, and no longer measurable in the alluvial system by the time the study commences in 2015. In localized areas there could still be some flood influences on the groundwater system, such as perched water tables.
- A more lasting environmental change from the 2013 flood favoring phreatophyte establishment was likely the significant geomorphologic changes due to extensive scour and deposition within the floodplain.
- Widescale phreatophyte and weed seed distribution by flood waters along the channel and in inundated areas resulting in new growth was likely.

The hypotheses were not intended to pre-judge study findings, but rather used to shape the study plan. The study was designed to test and either confirm or refute these hypotheses through review of published research, analysis of existing hydrology data, and extensive field work.

As described above a series of meetings with CSU and the BRT were conducted in the fall and winter of 2014-15 to develop the study plan and SOWs. Early in this process, the Board staff divided the study into two phases. Phase 1 focused on the science of identifying and inventorying the prevalence of phreatophytes, the relationship to groundwater influences, and groundwater changes due to the 2013 flood. Phase 1 work was within the specialized expertise of CSU and also built on previous groundwater work by the CWI (HB12-1278 alluvial aquifer study). Phase 2 involves estimating non-beneficial consumptive use by phreatophytes, developing control strategies and cost estimates based on the inventory work done in Phase 1, and writing the final report required by SB-195. The Tamarisk Coalition, a non-profit entity based in Grand Junction has unique abilities in all of these areas and in 2005-06 had conducted a ground based assessment of non-native phreatophytes along the South Platte mainstem. The Coalition was asked to submit a proposal for doing both the Phase 2 work and assisting CSU on Phase 1.

The study area was determined based on local input and flood related hydrology work being conducted by the Board's Watershed and Flood Protection Section. Using flood precipitation and runoff analysis mapping, areas where peak flood flows ranged from a 100 to 500 year recurrence interval were identified. Foothills and canyon areas where phreatophytes are not prevalent were excluded. This resulted in a study area where flood impacts on phreatophyte recruitment and growth were expected to be the greatest. The area consists of three tributaries: the St. Vrain, the Big and Little Thompson, and the Cache La Poudre, as well as the mainstem of the South Platte downstream of Ft. Lupton. The 2013 flood peaks attenuated (lower peak flows, but for a longer time duration) below Morgan Country, and the

region between Ft. Morgan and the state line with Nebraska, was not a major focus of field work, although it was included in the overall study area.

Phase 1 consists of the following main activities:

- Recognizing that research on these issues probably had been done, a literature review was needed to confirm or refute initial hypotheses, avoid duplication of efforts, and focus the analysis. Topics included
    - known relationships between flooding and phreatophyte establishment and growth, including groundwater depth, seed distribution, and geomorphologic changes
    - known relationships between flood stage, bank storage, and groundwater elevations as to magnitude and duration
- Field measurement of phreatophyte and noxious weed prevalence in selected test plots. Weeds are included because of their impact on revegetation efforts after initial control work is completed.
- Field data was linked to satellite imagery and aerial photos from the pre and post flood period to predict phreatophyte abundance and density changes at a basinwide scale.
- Using existing data, an assessment was conducted of the impact of the 2013 flood on groundwater levels in the study area.
- Results and findings, were documented in a Phase 1 report to the CWCB.

Phase 2 will:

- Use the Phase 1 abundance and density data to estimate non-beneficial consumptive use by both native and non-native phreatophytes.
- Develop control strategies and scenarios and associated costs.
- Hold stakeholder meetings to review study findings with local entities.
- Prepare a final report for the General Assembly documenting all study findings.

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5. CONSULTANT AGREEMENTS

The agreement with CSU to conduct Phase 1 of the study is contained in Purchase Order POGG1 PDAA 2015…0257, issued on April 2, 1015 in the amount of $99,733 with a completion date of December 31, 2016. A copy of the agreement, including the detailed SOW dated March 13, 2015, is included as an attachment to this report. As of December 31, 2015 $50,868 has been expended on this agreement.

The agreement for Phase 2 with the Tamarisk Coalition is contained in Purchase Order POGG1 PDAA 2016…0148, issued on July 15, 2015 in the amount of $42,150, of which only $19,070 is directly related to Phase 2 of the SB-195 study. The completion date is December 31, 2016. A copy of the agreement is included as an attachment to this report. As of December 31, 2015 approximately $8,000 has been expended on the SB-195 portion of this agreement.

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6. MAJOR TASK ACCOMPLISHMENTS

On December 31, 2015 CSU delivered a written progress report on Phase 1 to the CWCB staff. On February 8, 2016 staff attended a meeting with the principal CSU researchers for a further update on the study. Copies of the CSU progress report and the PowerPoints used at the update meeting are attached to this report.

A summary of Phase 1 progress and initial findings:

- Literature review
  - In progress, completion expected spring 2016
  - Generally supports initial hypotheses
  - Will include information on historical phreatophyte density changes since 1950s
- Field measurement of phreatophyte and noxious weed prevalence at 15 sites was completed in the summer of 2015
  - Over 5 miles of transect lines with a total of 873 10x20 meter plots sampled for species type, tree diameter, height, and canopy density
  - Cottonwood and willow predominate at 92% of the basal area, only 6% non-native phreatophytes (primarily Russian Olive)
  - Significant recruitment of new cottonwoods
  - Noxious weed data still being processed, but significant areas of cheatgrass and whitetop found
  - Evidence that flood inundation resulted in mortality of phreatophytes in some areas
  - No data yet on recruitment to new areas
- Predict phreatophyte abundance and density changes at a basinwide scale
  - Pre and post flood imagery from 2010 and 2013 processed
  - 2015 imagery available early 2016
  - Several models being tested and preliminary results calibrated and analyzed
- Impact of the 2013 flood on groundwater levels in the study area
  - Still assembling existing data, but indications are that any flood impacts were short term and out of the hydrologic system before study began
- Document results and findings in a Phase 1 report to CWCB
  - Not started

Phase 2 has not begun yet, but the Tamarisk Coalition has helped on Phase 1 field site selection and sampling protocols. The Tamarisk Coalition has also been involved in some non-SB-195 study pre-planning activities in the South Platte basin based on suggestions from Subcommittee input.

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7. ADDITIONAL CONSIDERATIONS

It is widely believed that native phreatophytes (cottonwood and willow) have increased in density and distribution over the last century in the South Platte basin, and that this vegetation has caused an increase in non-beneficial consumptive use of the basin's water supplies. While there is near universal consensus that control of non-native phreatophytes has positive benefits for water supply and environmental purposes, the control and removal of native phreatophytes could be controversial and use of public funds for that purpose raises policy issues that need to be considered. SB195 refers to "unwanted phreatophytes", deciding what that subjective term definitively means is beyond the scope of this study, but certainly has generated considerable discussion during meetings with stakeholders and water users. This study will document the prevalence of both natives and non-natives and include information on the costs of control of both without addressing the policy issues or recommending an approach to control of the native species.

While the 2013 flood was an extraordinary hydrologic event, it was followed by exceptional prolonged high water periods in the spring and early summer of 2014 and again in 2015. See the attached hydrographs for the South Platte at Ft. Lupton and at Ft. Morgan. These additional events make it difficult to assign the cause of changes observed in the 2015 field work to the 2013 flood. The 2015 high water also prevented access to some of the preferred sites for field work. Although it is currently believed that the groundwater table effects of the September 2013 flood were short term, the fact that there have been two years of high water following the flood event undoubtedly has caused increased water tables in the basin with a likely effect on the growth of both native and non-native phreatophytes.

Although no funds are currently available for this purpose it may be valuable to re-visit the field sampling sites and transects established in the SB-195 study at some point in the future. Ongoing changes in phreatophyte and noxious weed prevalence density could be assessed. Vegetative conditions over a longer time period since the 2013 flood may reveal slower to develop changes from that event.

During the outreach stage of study development discussions with the BRT, county weed managers, and water user groups highlighted a keen interest in aggressive efforts to control phreatophytes (non-native, and perhaps some native) throughout the basin. Based on this interest the Board has separately funded the Tamarisk Coalition to work with basin entities to develop project sponsor capacity and evaluate the adequacy of current control plans.

8. TIMELINE and SCHEDULE

Completed Activities

June 3, 2014	Initial CWCB – CSU discussions of project, Tom Holtzer at BioAg & Pest Management Dept.
June 6	Bill signed by Governor
June 17	Greeley Tribune article publicizing bill enactment
Aug. 12	CWCB & CSU meet with Phreatophyte Subcommittee of South Platte Basin Round Table (BRT) to discuss study approaches and local goals
Nov. 13	CWCB-CSU-CWI meeting to discuss roles and Scope of Work
Nov. 18	CWCB meet with Phreatophyte Subcommittee of South Platte BRT to discuss progress on study development
Nov. 20	Preliminary plan of study and budget presented to CWCB
Jan. 15, 2015	Discussion with South Platte BRT on basin phreatophyte issues and SB-195 study plan
Feb. 17	Meet with Phreatophyte Subcommittee of South Platte BRT to review SOW
Mar. 1-6	Comments on SOW from State Weed manager and Weld County Weed Supervisor
Mar. 13	CSU SOW finalized
Apr. 2	Purchase Order issued to CSU for Phase 1 of study
May	Site selection finalized, field work commences
July	Purchase Order issued to Tamarisk Coalition for Phase 2 of study
Dec. 31	CSU provides report on study progress and status
Feb. 8, 2016	CWCB staff met with CSU study team for progress update
March 16	CWCB Staff presented Draft Interim Report to Board for their review prior to its submission to the General Assembly

Remaining Work

Phase 1, CSU

January – May 2016:

- Using regression techniques create a map of tree and shrub abundance for the study area, based on the survey data and LiDAR imagery
- Followup field work if necessary
- Characterize groundwater changes, if any, resulting from September 2013 flood event
- Summarize initial findings from field work
- Finish literature review
- Processing of aerial photos will start directly after finishing the LiDAR processing. The images for 2015 will be available by the beginning of 2016
- Using the images of 2013 and 2015 detect any changes of the phreatophytes development between 2013 and 2015
- Integration of field data, LiDAR, and aerial photos to develop a predictive maps of phreatophyte and weed incidence and abundance in the whole study area
- Field verify predictive model results

- With available historical information and photos use model and GIS products to assess trends in phreatophyte densities during the 20th century

June, 2016: Draft report submitted to CWCB for review and comment.
August 2016: Final Phase 1 report to CWCB and Tamarisk Coalition

Phase 2, Tamarisk Coalition
January – May 2016:

- Continue collaboration with CSU on Phase 1 work
- Assess issue of increasing density of native phreatophytes

March – September 2016:

- Develop control categories for various densities of native and non-native phreatophytes, with consideration of restoration requirements
- Develop cost estimates for varying levels of control strategies and treatment methods
- Prepare draft final report on Phase 1 and 2

October – November 2016:

- Present draft Final Report to CWCB and South Platte Basin Round Table
- Revise draft as necessary

December 2016: Assist CWCB with presentation of Final Report to Colorado General Assembly

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ATTACHMENTS

A. SB14-195

B. Purchase Order POGG1 2015-0257 with Colorado State University

C. Purchase Order POGG1 2016-0148 with the Tamarisk Coalition

C. CSU Progress Report Dec. 31, 2015, with PowerPoint Slides

E. CSU Update PowerPoint presentation Feb. 8, 2016

F. South Platte at Ft. Morgan and at Ft. Lupton Hydrographs, Oct. 1, 2012 to Sept. 30, 2015

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