A Preliminary Green-Gray Analysis for the Cache la Poudre and Big Thompson Watersheds of Colorado's Front Range

Phase I Final Report

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Phase I Final Report:

1.0 Overview and key findings

An emerging hypothesis in an increasing number of environmental management settings is that investments in green infrastructure solutions provide economically superior ways to achieve environmental quality outcomes than conventional investments in technology-based or "gray" infrastructure. For example, the Center for Neighborhood Technology (2011) asserts "[t]he research shows that green infrastructure measures are as effective as conventional approaches in relieving flooding, and can be installed more cheaply and quickly." Moreover, green infrastructure is considered a lasting source of ecosystem service benefits for communities that appreciates rather than depreciates over time.

To this end, Center for Sustainable Economy (CSE) and World Resources Institute (WRI) have partnered with the Center for Collaborative Conservation to investigate the potential cost savings associated with investments in green infrastructure solutions to water quality issues in the Cache la Poudre and Big Thompson Watersheds of Colorado's Front Range. Combined, these watersheds span 1.73 million acres and provide drinking water to over 300,000 people who live in and around Fort Collins, Loveland, and Greeley.

In recent years, and especially in the wake of the destructive High Park Fire, concerns over the potential costs of catastrophic forest fires on drinking water supplies have spurred interest in investigating the potential economic benefits of green infrastructure solutions in the upper portions of each watershed that could reduce fire risk and restore watershed conditions. Meanwhile, at lower elevations near the cities, population growth coupled with new water quality regulations for nutrient pollution have generated interest in green infrastructure solutions that would obviate the need for expensive wastewater treatment upgrades and generate payments to farmers and ranchers who implemented best management practices. This analysis provides a preliminary Phase I assessment of cost-savings potential associated with green infrastructure options in both the upper and lower portions of Cache la Poudre (Poudre) and Big Thompson watersheds based on a limited set of assumptions and model inputs. Should further investigation be warranted, a Phase II study would provide more detail and more refined cost savings estimates across a wide range of assumptions.

To model these benefits, we first developed two basic scenarios that could unfold over the next twenty years. The first is a business as usual scenario or "gray" scenario where no additional green infrastructure investments take place, where the costs of wildfire remain high and utilities opt for conventional "gray" infrastructure upgrades to wastewater treatment facilities to meet new nutrient pollution standards. The second is a scenario where significant investments in thinning, fuel breaks and road decommissioning are made in the upper watershed to reduce fire risk and associated costs to drinking water and where water utilities opt for investments in best management practices on cropland and grazing land as an alternative to wastewater treatment plant upgrades. We then modeled the difference in economic costs under both scenarios over twenty years using the standard green-gray analysis (GGA) methodology first developed and applied by Talberth et al. (2013). The results provide a compelling case for further investigation of these green infrastructure options. Our key findings include:

- With no green infrastructure interventions, a series of catastrophic fires that would mimic the High Park Fire in terms of severity would likely generate nearly $760 million in costs in the form of fire suppression, restoration of burned lands, increased water filtration costs, lost recreational uses, carbon emissions, and damage to homes and other infrastructure.

- Investments in thinning, prescribed fire, forest restoration, fuel breaks and road decommissioning that include both expenditures by public agencies and payments to private landowners would reduce the risk of fire and reduce the costs of fires that do occur. Over a 20-year period, investing in an ambitious portfolio of these green infrastructure options could generate up to $320 million in savings after taking costs of implementation into account.

- In the lower watershed, new regulations limiting nitrogen and phosphorous discharges from wastewater treatment plants in Fort Collins, Greeley, and Loveland will cost over $31 million to implement through technological upgrades to existing plants. For Fort Collins and Greeley alone, these costs are just over $25 million.

- An assessment of nutrient reduction potential from cropland and grazing lands upstream from each city indicates that utilities in Fort Collins and Greeley could benefit from investing in best management practices in order to obviate the need for wastewater treatment plant upgrades. Investments in green infrastructure could represent a cost savings of over $15.4 million over a 20-year period.

- The magnitude of potential cost savings associated with green infrastructure options in both the upper and lower portions of the Cache la Poudre and Big Thompson watersheds warrants a more detailed investigation using biophysical models and better site-specific information on the availability, cost, and effectiveness of best management practices and fire risk reduction measures.

The remainder of this report is structured as follows. In section two, we provide details of the upper watershed scenarios developed for the analysis as well as the expected costs associated with the gray BAU and green infrastructure scenarios. In section three, we do the same for the lower watershed. In section four, we complete the green-gray analysis of these scenarios under three different sets of assumptions. In section five we offer concluding thoughts and suggest ways to approach the more detailed GGA analysis in Phase II.

2.0 Overview of the upper watershed scenario

After stakeholder consultations and preliminary review of information provided by the Forest Service, the City of Fort Collins Water Department and Greeley Water and Sewer Department, it became clear that catastrophic wildfire risk was overwhelmingly the greatest potential driver of impairment of source water quality in terms of cost to involved stakeholders and the public at large. Therefore, in order to target our preliminary analysis of green versus gray tradeoffs in the upper portions of the Poudre and Big Thompson Watersheds to capture the most significant costs and benefits, CSE and WRI are focused on catastrophic fire risk. In particular, we calculated rough order of magnitude estimates of the economic benefits of investment in a package of fire risk reduction and watershed restoration measures on Forest Service and private lands in the watersheds in terms of the avoided costs such measures generate for water utilities downstream, avoided suppression and rehabilitation costs for Forest Service and other entities and lost uses. We also incorporated the value of ancillary economic benefits such as carbon sequestration, avoided private property loss, preservation of passive use values[5] and recreational use.

[5] Passive use values represent people's willingness to pay for protection of particular environmental resources. Passive use values are established through scientific survey methods.

In order to complete the analysis, we first developed two basic scenarios:

(1) A business as usual (BAU) scenario that describes what is most likely to happen in terms of the frequency and severity of fires and their resultant costs both on site and downstream in the absence of any interventions, and;
(2) A green infrastructure (GI) scenario that describes the same after a series of fire risk reduction and watershed restoration measure are implemented.

Scenario details

Business As Usual (BAU) Gray Scenario

There are several existing assessments of fire risk and hazard for the Colorado Front Range, Larimer County and the Poudre and Big Thompson Watersheds. All of the assessments use some combination of criteria including values at risk, fuel hazard, fire regime-condition class, cumulative effects-effectiveness, soil erodability and water infrastructure risk. All of these could serve as the basis for a BAU fire scenario in Phase II of this analysis. For this preliminary Phase I assessment, we make the simplifying assumption that the BAU scenario would be a series of fires similar to the High Park Fire[6] in severity, but spread out over all remaining unburned "high risk" acres.

We further assume that all these unburned high-risk acres would burn sometime over the next twenty years. According to the Pinchot Institute for Conservation's pre- High Park Fire assessment (PIC 2007), there are 472,329 acres that meet these criteria and warrant fire risk reduction treatments. An earlier analysis by the Front Range Fuels Treatment Partnership Roundtable estimated that 272,162 acres warranted treatment (FRFTP 2006). To be conservative, we adopt the higher figure, but remove lands that have already burned in the High Park Fire from the analysis and so assume a residual high risk acreage of 444,719 acres.

The range of fire intensities in this BAU burn is assumed to match the pattern of burn in the High Park Fire. In the High Park Fire, 48% of the fire area was unburned or low severity, 38% was burned at moderate severity and 14% burned at high severity.[7] The probability of the BAU fire scenario unfolding is set at 100% over 20 years, or 5% per year. Alternative BAU scenarios could set this probability lower. Tables 1 and 2 summarize the extent and severity of the fire event assumed for the BAU scenario by ownership and by watershed. The distribution amongst owners and watersheds was based on spatial analysis of the high risk acres identified in the Pinchot (PIC 2007) analysis.

Table 1: Business As Usual Extreme Fire Event By Owner Class
(P=1.0 over 20 years)

Burned area	Federal	State & County	Private	Total
Unburned or low severity	109,616	11,117	92,869	213,603
Moderate severity	86,727	8,796	73,477	169,000
High severity	31,877	3,233	27,007	62,117
Total:	228,220	23,146	193,353	444,719

[6] At 87,487 acres, High Park was the largest recorded fire in the northern Front Range foothills.
[7] An alternative would be to peg the intensities to historical data. For example, it is estimated on national forests in the West from 1972 to 1998 burn area on average was 42% unburned and low severity fire, 30% moderate severity, and 28% high severity (Robichaud et al., 2000).

Table 2: Business As Usual Extreme Fire Event By Watershed
(P=1.0 over 20 years)

Burned area	Big Thompson	Poudre	Total
Unburned or low severity	96,949	116,653	213,603
Moderate severity	76,705	92,294	169,000
High severity	28,193	33,923	62,117
Total:	201,848	242,871	444,719

The consequences of a burn of this magnitude would be wide ranging, and generate significant short and longer-term costs for public agencies and user groups. First, there would be significant fire suppression costs incurred by both the Forest Service and other state and federal agencies. Post-fire, there would be several months of burned area rehabilitation, including soil stabilization, mulching and reseeding. For example, the High Park Fire resulted in $39.2 million in suppression costs ($448/acre) at the time of the Burned Area Emergency Response (BAER) report and the report forecast rehabilitation costs as an additional $24 million ($274/acre)[8] for a total of $63.2 million or approximately $722/acre (USFS 2012).

Before such stabilization and rehabilitation activities could be completed and certainly during and immediately following the fire, debris, sediment and ash delivery would spike during flooding events and contaminate rivers, streams, and reservoirs downstream. Treatment costs would escalate, mainly for manganese and turbidity. Although elevated manganese concentrations do not pose a health risk, those increased concentrations can pose water-treatment problems and can foster the growth of microorganisms in reservoirs and distribution systems (USGS 2012). Elevated erosion and associated turbidity is most predictable with high severity fire only and lasts from 1 to 4 years, but typically three or less (Robichaud et al. 2000; Moody and Martin 2001; Robichaud et al. 2003; Benavides-Solorio and MacDonald 2005; Robichaud et al. 2010).

Following fires in the Poudre Watershed, turbidity levels at water intakes for Fort Collins and Greeley would exceed critical thresholds for a period, causing these water utilities to switch to alternate water sources. Reservoir capacity would decrease from sedimentation, limiting supplies during drought or dry seasons and thus would require additional dredging. The 1997 Buffalo Creek and 2002 Hayman Fires forced Denver Water to spend more than $30 million on dredging Strontia Springs Reservoir.[9] Following fires in the Big Thompson Watershed, manganese levels would rise in Horsetooth Reservoir and Boyd Lake. Manganese treatment costs using oxidation with potassium permanganate could add roughly $500,000 per year.[10] On site for fires in either watershed, most forms of recreation would be lost or displaced.

As with all destructive wildfires, there would be significant losses to property and infrastructure. Insured losses during the High Park Fire were $113.7 million, or $2,710 for each acre of private land burned at moderate or high intensity. The operation of farms, ranches, and businesses within the affected region could be impaired for a significant period. Nearby property values may decline. Passive use values associated with intact roadless and wilderness lands would be lost. An assessment by Loomis and Richardson (2000) calculated an annual per acre passive use of $6.72 for the western U.S., exclusive of

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[8] The distribution of these rehabilitation costs were forecast as follows: Forest Service: $7.3 million, NRCS/EWP $9.9 million, and Larimer County $6.8 million.
[9] There are various estimates for this, some which include watershed rehabilitation. But the most recent estimate of actual dredging costs are reported here: http://www.elevationoutdoors.com/biking/restoring-hayman/.
[10] Extrapolated from a 40,000 customer service area studied by Crocker et al. (2011).

Alaska. An analysis by CSU's Dennis Lynch following the Hayman Fire in 2002 estimated the loss of passive use values on wilderness and roadless lands to be $5.64 per acre (Rine 2005).

As with all wildfires, there would be a spike in emissions of stored carbon dioxide as vegetation burns. For wildfire, it has been estimated that 41.0 megagrams of carbon per hectare (mg C/ha) are emitted in the lower 48 (EPA 2011). Using current federal guidance on the social costs of carbon ($36/metric ton CO2-equivalent) this translates into a damage estimate $1,476 per hectare, or roughly $600 per acre. While the magnitude of these costs would be difficult to predict, all are likely to manifest in fires as intense and widespread as those expected under the BAU scenario. Table 3 summarizes the BAU scenario in terms of the extent of the fires, cost elements, and duration of such costs. All costs are expressed in real time nominal units in values that correspond to the time period in which they were incurred. For this Phase I assessment, we assume that the BAU fire scenario would generate nearly $760 million in costs.

Table 3: Midpoint Cost Estimates for BAU Fire Event

Cost element	Units	Impact/ extent	Duration	Real time cost
Fire suppression	acres	444,719	event	$199,234,112
Burned area rehabilitation	acres	231,116	3 years	$63,325,908
Turbidity (Poudre)	ntu	Increases from 2 to 100+	1 year	$2,000,000
Manganese (Poudre)	Mg/l	Increases from .03 to .50	90 days	$500,000
Reservoir dredging costs	dollars	Northern Water reservoirs	event	$30,000,000
Alternate water sources	days	Loveland	30 days	$100,000
Lost recreational use	visits	- 673,092	1 year	$41,334,576
Lost passive use values	acres	-48,552 roadless acres	50 years	$11,830,287
Carbon emissions	tons	3.85 million tons released	event	$138,669,871
Insured property losses	dollars	$2,710/acre on pvt land	event	$272,276,856
			Total:	$759,294,610

Green Infrastructure Scenario (GI)

The green infrastructure scenario we analyzed included a package of fuel breaks, thinning and prescribed fire treatments cited in PIC 2007. The Pinchot Institute for Conservation (2007) estimated that 472,329 acres of critical watershed with high hazard rating would require treatments (269,407 acres in the Cache la Poudre watershed and 202,922 in the Big Thompson watershed). On the other hand, the Front Range Fuels Treatment Partnership roundtable (2006) estimated 272,162 acres requiring treatments in Larimer County with 60% in private ownership. Here, we adopt the higher PIC figure.[11] The precise location of the high hazard treatment areas will be refined during the next phase of this work, as will the expected benefits in terms of reduced fire risk and risk of deleterious impacts.

Hazardous fuels treatments (including thinning and prescribed burning) and fuel break construction costs vary widely but have been estimated for the analysis area by PIC (2007) and the FRFTP Roundtable (2006). Those estimates were based on 2004 Forest Service data. The FRFTP Roundtable (2006) estimated prescribed burning costs to be $125/acre and mechanical costs to be from $400 to $800/acre. The PIC (2007) used a figure of $875/acre on average for all treatments based on personal communication with Forest Service Staff on the Arapaho-Roosevelt National Forest.

Also included in this package is a level of investment in road decommissioning sufficient to substantially reduce the risk of human-caused fire and sediment delivery should a fire occur. The scenario includes projects that are already in the pipeline on Forest Service lands as well as hypothetical projects that could

[11] It was not possible to back out the High Park Fire acres from this estimate. Nor is it necessary to do so since treatments also include restoration of damaged areas. So we left the total acreage recommended here intact.

be implemented on federal and private lands. Funding for private land treatments could be generated by future payments for watershed services (PWS) schemes or provided by one of several NRCS or USDA Cooperative Forestry programs. We assume that all activities would be completed over a five-year period. Table 4 provides an overview of the GI scenario.

Table 4: Green Infrastructure Scenario By Owner Class

Activity	Federal	State & County	Private	Total
Thinning, prescribed fire and restoration (acres)	153,926	16,020	243,497	413,433
Fuel breaks (acres)	21,927	2,282	34,687	58,896
Road decommissioning (miles)	438	71	509	1,018

The anticipated benefits of these treatments will be refined with more detailed analysis completed as part of Phase III of this project. For this preliminary exercise we extrapolated expectations from the literature. In terms of the anticipated fire regime, we assume that the treatments would reduce the probability of a large fire (with identical acreage as the BAU scenario) by half and substantially reduce each of the cost elements included in Table 3. Should a fire occur, we assume that the pattern of burn severity would again mimic the proportions found in the 2012 High Park Fire except that all lands that would otherwise burn at high severity would burn at low severity as a result of effective treatments (Tables 5 and 6).

Table 5: Green Infrastructure Fire Event By Owner Class
(P=0.5 over 20 years)

Burned area	Federal	State & County	Private	Total
Unburned or low severity	141,493	14,350	119,876	275,719
Moderate severity	86,727	8,796	73,477	169,000
High severity	0	0	0	0
Total:	165,570	17,232	261,917	444,719

Table 6: Green Infrastructure Large Fire Events By Watershed
(P=0.5 over 20 years)

Burned area	Big Thompson	Poudre	Total
Unburned or low severity	150,577	125,143	275,719
Moderate severity	92,294	76,705	169,000
High severity	0	0	0
Total:	242,871	201,848	444,719

Fire suppression costs would be reduced not only because of the reduced risk of ignition but increased flexibility to allow lands formerly classified at high risk to burn naturally. Rehabilitation costs would be minimal since the burn, should it occur, would be largely beneficial. Impacts to water quality, reservoir capacity, and lost use and non-use values would also be eliminated or minimal by effective road decommissioning and beneficial thinning. Carbon emissions would be substantially cut. Table 7 presents the anticipated costs associated with the GI scenario should a large fire occur. For this Phase I preliminary assessment, we assume that should a large fire occur, costs under the GI scenario would be nearly $300 million less ($461 million) than the BAU scenario. This figure was calculated as the difference in the cost assumptions used in Table 7 relative to those reported in Table 3.

Table 7: Midpoint Cost Estimates for Green Infrastructure Scenario Fire Event

Cost element	Units	Impact/ extent	Duration	Real time cost
Fire suppression	acres	169,000	event	$75,712,000
Burned area rehabilitation	acres	169,000	3 years	$46,306,000
Turbidity (Poudre)	ntu	Increases from 2 to 100+	-	$0
Manganese (Poudre)	Mg/l	Increases from .03 to .50	-	$0
Reservoir dredging costs	dollars	Northern Water reservoirs	-	$0
Alternate water sources	days	Loveland	-	$0
Lost recreational use	visits	- 492,187	1 year	$30,225,211
Lost passive use values	acres	-35,502 roadless acres	50 years	$8,650,448
Carbon emissions	tons	2.82 million tons released	event	$101,400,000
Insured property losses	dollars	$2,710/acre on pvt land	event	$199,097,287
			Total:	$461,390,946

3.0 Overview of the lower watershed scenario to be modeled

In June 2012, the Water Quality Control Commission of the Colorado Department of Public Health & Environment (CDPHE) promulgated Regulation 85—Nutrients Management Control Regulation. The regulation imposed numeric nutrient standards on wastewater treatment facilities (WWTFs) through the Colorado Discharge Permit System (CDPS). A 2011 study contracted by the Colorado Water Resources and Power Development Authority estimated that WWTFs in the entire Platte River Basin will incur nearly $1.5 billion in costs over a 25 year period for necessary nutrient control technology to meet the new effluent limits. However, Regulation 85 provides dischargers with flexibility in achieving the concentration reductions the new effluent limits are geared to meet by allowing for trading schemes involving nonpoint sources of nutrients like farms and ranches.

In this analysis, CSE and WRI investigate the cost-effectiveness of such an alternative scenario that involves payments to private landowners in exchange for reductions in nutrient runoff from farms and ranches in the Big Thompson and Cache la Poudre watersheds. In particular, we estimated the costs of achieving required nutrient reductions through various nonpoint source best management practices (BMPs) relative to the costs of nutrient control technology options available to wastewater utilities in Fort Collins, Greeley, and Loveland.

In order to complete the analysis, and as with the upper watershed, two detailed scenarios were developed:

(1) A gray infrastructure scenario that describes the costs of meeting nutrient reduction requirements with traditional nutrient control technology, and;
(2) A green infrastructure scenario that describes the costs of meeting nutrient reduction requirements by implementing best management practices on upstream farms and ranches.

<u>Scenario details</u>

Business as Usual (BAU) Gray Scenario

Under the gray scenario, wastewater utilities in Fort Collins, Greeley, and Loveland implement needed nutrient control technologies on schedule to meet compliance dates assigned by CDPHE. Compliance dates are not yet known, and will not be determined until the renewal date for each utility's permit under the National Pollution Discharge Elimination System (NPDES). Renewal dates are scheduled for 2013, 2015, and 2017 for Fort Collins, Loveland, and Greeley, respectively. However, CDPHE has indicated that the earlier renewal dates may be pushed back to 2016-2017 such that review for Regulation 85 compliance can occur at once for all utilities in the South Platte. Compliance will be required immediately upon permit renewal only for those utilities able to meet the new nutrient limits with already-installed technology. For utilities requiring investments in new technology, the agency expects to provide an additional five years (potentially longer) to identify, finance, and install needed technology. For the purposes of this analysis, we assume under the BAU scenario that capital investments in nutrient control technology occur in 2020 for each of the three utilities, and that annual operations & maintenance costs are incurred thereafter.

Estimated annual nutrient reduction needs are calculated based on typical current effluent concentrations relative to the limits prescribed by Regulation 85 and extrapolated based on total annual discharge volume. Planned capital expenses for nutrient control technology are reported directly by the three wastewater utilities. Operations & maintenance (O&M) costs are based on per gallon estimates used in a study contracted by the Colorado Water Resources and Power Development Authority. The details of each utility's compliance options are as follows:

Loveland: The wastewater treatment facility in Loveland discharges into the Big Thompson River downstream of Loveland. Based on Regulation 85 limits and Loveland's actual TIN and TP effluent concentrations in the first six months of 2013, Loveland must reduce average effluent concentrations for TIN by about 1.8 mg/L, and 2.6 mg/L for TP.[12] Given current and projected annual discharge volume, we estimate that the utility must reduce TIN effluent by about 41,000 lbs per year, and TP by about 59,000 lbs. To address these effluent limits, Loveland plans to invest in nutrient control technology with a capital cost of $6.3 million. In addition, the utility estimated that it might occur as much as $100,000 throughout a given year in O&M costs, primarily for chemicals if the biological treatment system goes down.

Fort Collins: The City of Fort Collins operates two wastewater facilities—Mulberry and Drake. The Mulberry facility discharges directly into the Cache la Poudre River. In 2010, in anticipation of Regulation 85 limits, the City reconstructed the Mulberry plant with biological nutrient control technology at a cost of $30 million. The facility is now meeting Regulation 85 limits for both TIN and TP. The Drake facility has undergone the first phase of a similar reconstruction on its north "train." The south train has not yet been updated, but has been temporarily decommissioned for efficiency purposes. Updating the south train would incur a capital cost of $4.6 million. The utility asserts that *additional* O&M costs are negligible given the lack of need for chemicals in the biological operation. However, given the O&M costs expected by Loveland for backup chemicals for its similar system, we assume Fort Collins would incur similar costs, scaled down to match the discharge rate of the Drake facility—$53,000 annually. Currently, average effluent concentrations from the Drake Facility are meeting Regulation 85 limits for TIN, while the facility must reduce TP concentrations by 2.5 mg/L. Given current and projected annual discharge volume, we estimate that the facility must reduce annual TP discharge by about 30,000 lbs.

Greeley: Greeley Water & Sewer did not provide data for this analysis. In lieu of reported data, we pulled together publicly available information and closed gaps with conservative assumptions. Greeley's waste water facility has a rated annual average flow capacity of 16.0 mgd and discharges roughly 7.5 mgd on average. We assume the city's discharges will increase over the following 20 years, averaging 10 mgd. Based on capital and O&M costs reported by Fort Collins and Loveland and those utilities respective discharge rates, we assume that Greeley will incur $10 million in capital costs for new nutrient treatment technology and $133,000 annually in additional O&M costs. Without reported data for current nutrient

[12] Note: Regulation 31 in Colorado authorizes CDPHE to implement tighter nutrient limitations than those prescribed by Regulation 85 depending on the circumstances. While tighter limits are a possibility, conversations with agency staff have indicated that they are unlikely within the near to mid term.

concentrations in Greeley's discharge, we assume the utility must reduce annual TIN discharge by 2.5 mg/L and annual TP by 0.5 mg/L. This amounts to 76,000 lbs for TIN and 15,000 lbs for TP.

Table 8: Nutrient Control Technology Costs, 2020-2040

Utility	Capital outlays	Annual O&M
Fort Collins (Drake)	$4,600,000	$53,000
Greeley	$10,000,000	$133,000
Loveland	$6,300,000	$100,000
Total:	$20,900,000	$286,000

Green Infrastructure Scenario (GI)

The green infrastructure scenario includes a package of best management practices on farmland and ranchland that are demonstrated to reduce nutrient runoff. These investments in green infrastructure could be made immediately, and obviate the need for gray infrastructure upgrades further out in time. Farmland practices include residue management and cover crops, nutrient management, and irrigation water management. Ranchland practices include rotational grazing, riparian fencing, and rotation of supplements and feeding areas.

In order for nonpoint source to point source trading to receive regulatory approval, the scheme must provide nutrient concentration/loading reductions equal to, or greater than, the reductions resulting from the effluent limitations authorized by Regulation 85, and must generally produce a "net water quality or environmental benefit" as determined by CDPHE. The agency recommends a nutrient trading ratio of 2:1 for nonpoint source to point source trades, although this ratio could be revised based on site-specific data that demonstrates that a net benefit will be achieved with a lower ratio. For the purposes of this analysis, we will use the 2:1 ratio (i.e., farms and ranches must reduce 2 mgs of total phosphorus or total inorganic nitrogen in order to offset 1 mg in the effluent limits faced by a WWTF).

Additionally, trading must not cause "adverse localized impacts." For example, a trade between a WWTF plant and a nonpoint source 20 miles downstream of the WWTF discharge point might cause such localized impacts in the 20-mile stretch of stream between the two parties. While the net nutrient concentration of the stream may be reduced through the trade, the stream segment immediately downstream of the WWTF discharge point would not see any of the improvement intended to be achieved by Regulation 85. Identifying potential for localized impacts can be a complicated matter. For the purposes of this preliminary analysis, we assume that all nonpoint source nutrient reductions must occur *upstream* of the WWTF discharge points.

The acreages currently used for grazing cattle and producing crops upstream of the discharge points for each WWTF are shown in Table 9 below. For grazing lands, we assume a 25% utilization (occupancy) rate in a given year, and so the figures reported in Table 9 are roughly ¼ of the total land available for grazing upstream from the three cities. Loveland acreage reported is in the Big Thompson Watershed. Acreages reported for Fort Collins and Greeley are both in Cache la Poudre Watershed. Note that some acres reported for Greeley and Fort Collins are duplicate. In other words, the acres shown for Greeley are *all* the acres upstream of the utility's discharge point, including those acres upstream of Fort Collins' discharge point. If both Fort Collins and Greeley choose to participate in a non-point source trading scheme, the program would require that the utilities secure unique non-point sources to trade with.

Table 9: Nonpoint Source Acreage Upstream of Discharge Points

Utility	Utilized Grazing*	Crops
Fort Collins above Fossil Ditch	90,361	27,795
Greeley	102,268	139,378
Loveland	20,504	4,545
Total:	213,133	171,718

** Assumes a 25% utilization rate of rangelands*

Estimating nutrient reduction potential from implementation of BMPs in the study area is an exceedingly complex task without detailed local data and modeling. Table 10, below, presents preliminary estimates based on a number of local and non-local sources. To derive these estimates, we first estimated the average annual nutrient load for the Cache la Poudre River at Greeley based on concentration data recently compiled and presented by Son (2013) and an average annual flow estimate of 300,000 acre feet from Varra (2011). Based on previous studies of the South Platte Basin (Litke 1996) we then allocated 50% of that load to cropland, and 30% to pastures. The remaining 20% is assumed to originate from wastewater, stormwater runoff, and other non-agricultural sources.

Dividing these loads by the acres of cropland and utilized rangeland above Greeley yielded per-acre delivered load estimates as follows: cropland TIN (6.32 lbs/acre), cropland P (2.25 lbs/acre), grazing land TIN (5.17 lbs/acre), and grazing land TP (1.84 lbs/acre). Edge of field loads are generally 2-5 times higher. These ballpark loading figures are generally consistent with findings from other watersheds with similar agricultural land use intensities. To these load estimates, we then applied nutrient reduction efficiency estimates from a number of sources including WRI (2012)[13] and the USDA's Conservation Effects Assessment Project (CEAP 2012) for the Upper Mississippi River Watershed.

Table 10: Estimated Delivered Nutrient Reduction Potential per Acre

BMP	lbs TIN/acre	lbs TP/acre
Residue management & cover crops	1.71	0.17
Nutrient management	0.57	0.42
Irrigation water management	1.14	0.90
Rotational grazing	0.57	0.44
Riparian fencing	3.77	1.23
Rotation of supplements & feeding areas	0.57	0.44

Drawing on the per acre estimates in Table 10 above and the assumed acreage available for BMP implementation upstream of each WWTF's discharge point, Table 11 below provides estimates of total nutrient reduction potential from upstream nonpoint sources. The estimates assume that BMPs are maintained over the entire 20-year study period.

[13] In 2012, WRI completed a project with the Economic Research Service analyzing the benefits of switching to a pay for performance platform for cost share assistance. The database developed for that contained over 12,000 data points for agricultural and pasture BMPs.

Table 11: Total Annual Nutrient Reduction Potential from Upstream Nonpoint Sources

Utility	lbs TP	lbs TIN
Fort Collins	305,711	858,123
Greeley	502,103	1,409,390
Loveland	47,984	134,690

Using the 2:1 trading ratio, these results indicate that there is more than sufficient nutrient reduction potential from upstream nonpoint sources to offset major technological investments at each WWTF—*except* for Loveland, where upstream sources could not reduce enough TP to meet the utility's reduction needs. For the other utilities, the remaining question is whether complying with Regulation 85 by trading with nonpoint sources is a cost-effective option for the two WWTFs, relative to investments in conventional nutrient control technology (the gray scenario). This will be answered in Section 4. But in order to do so, we must first specify a reasonable portfolio of green infrastructure options to model.

There are a variety of approaches for constructing a green infrastructure portfolio designed to help participating utilities meet their nutrient reduction goals. One approach is to assume that the mix of BMPs selected is based on cost effectiveness – i.e, all least cost options are exhausted first before higher cost BMPs are added. However, the complexities of this approach are formidable, including, for example, significant unknown or highly variable cost factors such as transaction costs, land rental rates, and commodity prices over time. An alternative, more tractable approach is to base the modeled portfolio on current implementation rates by farmers and ranchers. Regionally, the current implementation rates for each of the BMPs we consider range from 20-50%, so a portfolio that includes each is a reasonable approach.[14] Table 14 below shows one evenly mixed portfolio of BMPs that would accomplish the required nutrient reduction goals for Fort Collins and Greeley. We use this as the basis of our GGA in Section 4.

Table 12: Sample Mixed BMP Portfolios By Utility

Utility	BMP	Acres
Fort Collins	Residue management & cover crops	5,000
	Nutrient management	5,000
	Irrigation water management	20,000
	Rotational grazing	10,000
	Riparian fencing	21,000
	Rotation of supplements & feeding areas	20,000
Greeley	Residue management & cover crops	17,000
	Nutrient management	3,000
	Irrigation water management	20,000
	Rotational grazing	14,000
	Riparian fencing	21,000
	Rotation of supplements & feeding areas	20,000

4.0 Green Gray Analysis

In this section we take the data presented for each scenario and complete a preliminary green-gray analysis (GGA) using standard modeling techniques synthesized by Talberth et al. (2013), but based on standard public infrastructure investment analysis. The general approach involves using a spreadsheet-

[14] Personal communication with John Fusaro, Natural Resources Conservation Service. August 26th, 2013.

based model to compare the present value costs of both green and gray options taking into consideration capital, or up front costs of green and gray infrastructure options, annual operations and maintenance costs, the opportunity costs of capital, a discount rate, and an analysis period. GGA analysis is intended to serve one of three purposes: (1) identify the least-cost manner for meeting regulatory requirements; (2) identify the least cost approach for achieving target levels of public good provision, or (3) determine the cost effectiveness of green infrastructure solutions in minimizing the costs of natural disasters (Talberth et al.2013). In the upper watershed, our GGA is intended to serve the third purpose, in the lower watershed, the first.

4.1 Upper Watershed GGA

Approach

For the upper watershed analysis, we determined the cost effectiveness of investments in fire risk reduction by comparing the present value costs of the BAU and GI fire scenarios, as described before. As noted in Tables 1-3 we assume that the BAU fire scenario would result in a series of fires 444,214 acres of high-risk lands in both watersheds resulting in nearly $760 million in costs. We assume that the fires would occur with certainty (100% probability) over a 20-year period. In any given year, this means that we are assuming a 5% chance of these fire costs being incurred. Thus, the expected cost in any one year is roughly $38 million. At a 3% discount rate, the present value of this stream of expected BAU costs over twenty years is $564.82 million.

For the GI scenario, we assume thinning, prescribed fire, restoration, fuel breaks and road decommissioning would lower the risk of fire to 50% in twenty years. If such a burn happened, we assume that the same 444,214 acres of land would burn as in the BAU scenario, but that all lands expected to burn at high severity would instead burn at low severity due to effective fire risk reduction treatments (Tables 5 - 6). This would lower costs to $461.39 million (Table 7) should a fire occur, which translates into an annual expected value cost of roughly $11.5 million and a present value of $171.61 million. But to achieve this cost savings, significant investments would have to be made in green infrastructure options. We assume that the necessary investments would occur over a 5-year period. In addition, for road decommissioning, there are periodic maintenance requirements every five years or so that need to be factored in. Table 13 presents the unit cost ranges assumed in our analysis. The data are derived from a number of Forest Service and independent research publications including PIC (2007), Front Range Partnership (2007), USFS (2012), USFS (2013) and Wildlands CPR (2003). The total costs of each GI option were obtained by multiplying the acreages and mileages in Table 4 by these unit costs.

Table 13: Green Infrastructure Cost Assumptions

Activity	Unit cost range	Mean
Thinning, prescribed fire and restoration (per acre)	$114-$786	$401.00
Fuel breaks (per acre)	$550-$900	$725.00
Road decommissioning (per mile)	$1,126-$2,500	$1,813.00
Road decommissioning annual maintenance (per mile)	-	$134.50

With GI costs in hand, we then developed three GGA modeling cases to compare green versus gray. In case 1 (Baseline) we assume a 20-year analysis period, a 3% discount rate, the 20-year probability of fire as 100% for BAU and 50% for GI, and unit costs for green infrastructure options as the mean values reported in Table 13. In case 2 (Low Gray) we modeled a less optimistic scenario for green infrastructure by reducing the 20-year probability of fire to 50% for BAU and 25% for GI, increasing unit costs to the high end of the ranges reported in Table 13. In case 3 (Low Green) we modeled a more optimistic scenario for green infrastructure by restoring the fire probabilities to that used in Case 1 and by using unit costs on the low end of the ranges.

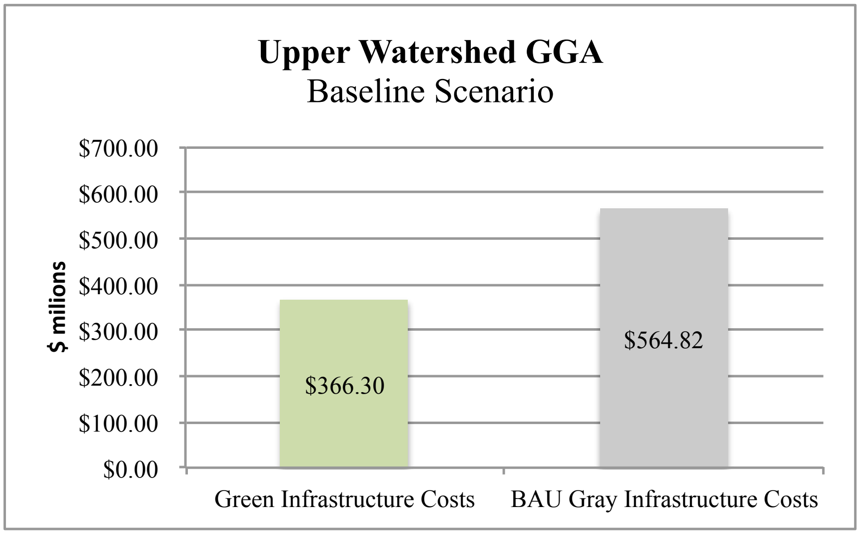
Results

The results for each case are reported in Table 14. Figure 1 depicts the results for case 1, the Baseline. As shown in Table 14, under the Baseline, investing in an ambitious package of green infrastructure solutions on federal, state, and private lands would results in a present value cost savings of nearly $200 million, or roughly 35% less BAU. Under more optimistic assumptions for green infrastructure, those cost savings increase to $317 million, a 56% reduction with respect to BAU under the Low Green case. On the other hand, under the Low Gray case, the level of investment in green infrastructure we modeled would not be cost effective. In this case, the green infrastructure scenario costs $154 million, or nearly 55% more than the expected BAU cost of $282.41 million. The most important factor driving the different outcomes is the probability of the BAU fire over a twenty-year period. Through iterative runs of the spreadsheet-based model varying that probability and nothing else, it appears that if that probability is roughly 50% or less, the level of investment in green infrastructure would have to drop – but be just as effective in halving fire risk – to be economically justifiable.

Table 14: Green versus Gray Results for the Upper Watershed

Cost element	Scope	Present value
Case 1: Baseline		
BAU fire scenario (gray)	444,719 acres	$564,819,324
GI fire scenario	444,719 acres	$171,608,305
Thinning, prescribed fire and restoration	413,433 acres	$151,850,847
Fuel breaks	58,896 acres	$39,110,333
Road decommissioning	1,018 miles	$1,690,493
Road decommissioning maintenance	1,018 miles	$2,037,039
Total green		$366,297,016
Green minus gray		$198,522,307
% cost savings		35.14%
Case 2: Low Gray		
BAU fire scenario (gray)	444,719 acres	$282,409,662
GI fire scenario	444,719 acres	$85,804,153
Thinning, prescribed fire and restoration	413,433 acres	$297,642,807
Fuel breaks	58,896 acres	$48,550,758
Road decommissioning	1,018 miles	$2,331,071
Road decommissioning maintenance	1,018 miles	$2,037,039
Total green		$436,365,828
Green minus gray		-$153,956,166
% cost savings		-54.15%
Case 3: Low Green		
BAU fire scenario (gray)	444,719 acres	$564,819,324
GI fire scenario	444,719 acres	$171,608,305
Thinning, prescribed fire and restoration	413,433 acres	$43,169,567
Fuel breaks	58,896 acres	$29,669,908
Road decommissioning	1,018 miles	$1,049,914
Road decommissioning maintenance	1,018 miles	$2,037,039
Total green		$247,534,733
Green minus gray		$317,284,590
% cost savings		56.17%

Figure 1



4.1 Lower Watershed GGA

Approach

For the lower watershed analysis, we compared the present value costs of wastewater treatment upgrades with a GI scenario that includes a mixed portfolio of cropland and grazing land BMPs that would achieve the same level of nutrient reduction. As detailed in Table 8, we assume that the BAU regulatory compliance scenario would cost wastewater utilities in Fort Collins, Greeley, and Loveland roughly $20.9 million in up front capital costs and another $286,000 in operations and maintenance costs each year. Using EPA's standard two stage discounting procedure, a cost of capital set at 7%, and a discount rate of 3%, this translates into a present value cost of $33.61 million, of which $26.12 million would be for Fort Collins and Greeley.

For the GI scenario, we assumed that the mix of BMPs specified by Table 12 would generate two times the amount of nutrient reduction required for two utilities – Fort Collins and Greeley – to meet their nutrient reduction goals set by Regulation 85. This reflects the required trading ratio of 2:1 for any future nutrient trading program. For Loveland, there did not appear to be a sufficient amount of phosphorous reduction potential available upstream, so we exclude that WWTP upgrade from the analysis.

In terms of costs, there are up front or installation costs to consider in addition to annual costs, including any maintenance of new equipment or infrastructure. Table 15 contains our baseline cost assumptions for each BMP used in the analysis. These data were based on cost share figures provided by USDA-NRCS. For BMPs that require such infrastructure, there is also the issue of practice life. Most BMPs that require infrastructure like new watering troughs or fences need to be replaced on some known interval. Based on previous work in the Chesapeake Bay watershed, we assume that two BMPs (rotational grazing and riparian fencing) would have a practice life of 10 years, thus requiring two rounds of installation costs over the analysis period.

A final consideration is net, rather than gross costs. For many BMPs, after an initial period of implementation, they essentially pay for themselves by helping farmers and ranchers reduce costs and improve productivity. At this point, external funding would not be needed to ensure their implementation.

Based on personal correspondences with NRCS staff, residue management, cover crops, nutrient management and irrigation water management are likely to break even by paying for themselves after 3 years. To account for this, we adjusted the analysis to use a weighted average cost figure over a 20-year period. So, for example, the cost of residue management used in the model was $4.86 per acre per year, which is $32.43 per acre for three years, zero for seventeen.

Table 15: Green Infrastructure Cost Assumptions

Best management practice	Installation costs ($/acre)	Annual costs* ($/acre)	Practice life (Years)
Residue and tillage management	$0.00	$32.43	1
Cover crops	$0.00	$43.17	1
Nutrient management	$0.00	$57.79	1
Irrigation water management	$0.00	$18.46	1
Rotational grazing	$40.00	$0.00	10
Riparian fencing	$40.00	$0.00	10
Rotation of supplements & feeding areas	$0.00	$1.00	1

* *Gross costs, not including producer benefits.*

Using these GI costs, as with the upper watershed, we then developed three GGA modeling cases to compare green versus gray. In case 1 (Baseline) we assume a 20-year analysis period, a 3% discount rate, a 7% opportunity cost of capital, and unit costs for green infrastructure options as reported in Table 15, but adjusted to net rather than gross costs over the 20-year period. In case 2 (Low Gray) we modeled a more optimistic scenario for gray infrastructure by lowering the cost of capital to 5%, by assuming that cover crops rather than residue management would be used. In case 3 (Low Green) we modeled a more optimistic scenario for green infrastructure by increasing the cost of capital back to 7%, by assuming that re-installation of riparian fencing and feeding area structures would not be necessary, and by altering the mix of BMPs in accordance with USDA-NRCS recommendations, including a substantial lowering of the need for riparian fencing.

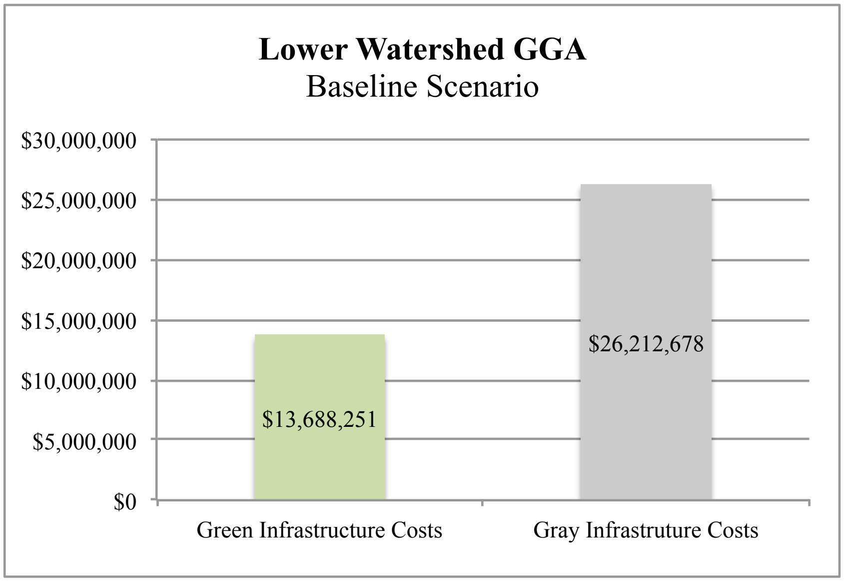
Results

The results for each case are reported in Table 16. Figure 2 depicts the results for case 1, the Baseline. As shown in Table 16, under the Baseline, investing in green infrastructure alternatives to wastewater treatment plant upgrades in Fort Collins and Greeley would result in a present value cost savings of nearly $12.5 million, or nearly 48%. Under more optimistic assumptions for green infrastructure, those cost savings increase to $15.4 million, or over nearly 69% less in the Low Green case. Even with less optimistic assumptions for green infrastructure, the cost savings would be substantial. The Low Gray case still indicates that green infrastructure would be superior, saving over $9.8 million, or roughly 43%. Thus, at least under the three cases we considered, green infrastructure seems a superior investment despite the conservative assumptions we have made for the lower watershed.

Table 16: Green versus Gray Results for the Lower Watershed

Cost element	Scope	Present value
Case 1: Baseline		
BAU WWTP upgrades (gray)	FC & Greeley	$26,212,678
Residue management & cover crops	22000 acres	$1,592,172
Nutrient management	8000 acres	$1,031,723
Irrigation water management	40000 acres	$1,647,829
Rotational grazing	24,000 acres	$3,624,688
Riparian fencing	35,000 acres	$5,286,004
Rotation of supplements & feeding areas	34,000 acres	$505,834
Total green		$13,688,251
Green minus gray		$12,524,427
% cost savings		47.78%
Case 2: Low Gray		
BAU WWTP upgrades (gray)	FC & Greeley	$22,725,877
Residue management & cover crops	22,000 acres	$2,119,460
Nutrient management	8,000 acres	$1,031,723
Irrigation water management	40,000 acres	$1,647,829
Rotational grazing	24,000 acres	$3,081,315
Riparian fencing	35,000 acres	$4,493,585
Rotation of supplements & feeding areas	34,000 acres	$505,834
Total green		$12,879,747
Green minus gray		$9,846,131
% cost savings		43.33%
Case 3: Low Green		
BAU WWTP upgrades (gray)	FC & Greeley	$26,212,678
Residue management & cover crops	22,000 acres	$1,153,976
Nutrient management	8,000 acres	$864,229
Irrigation water management	40,000 acres	$1,380,314
Rotational grazing	24,000 acres	$2,567,488
Riparian fencing	35,000 acres	$755,143
Rotation of supplements & feeding areas	34,000 acres	$299,093
Total green		$7,020,244
Green minus gray		$15,414,631
% cost savings		68.71%

Figure 2



5.0 Concluding Thoughts and Suggested Refinements for the Phase II Analysis

Although our analysis is preliminary, and based on a significant number of assumptions that need to be revisited in Phase II, our green-gray results for both the upper and lower portions of the Cache la Poudre and Big Thompson watershed are promising. An ambitious, yet achievable portfolio of fire risk reduction and watershed restoration measures in the upper watershed could reduce fire-related costs by nearly $320 million over 20-years, after taking implementation costs into account. In the lower watershed, a nutrient trading program that financed best management practices on cropland and grazing land above Fort Collins and Greeley could help those cities meet nutrient reduction targets for the wastewater sector at a greatly reduced cost between $9.8 to $15.4 million.

The potential magnitude of these cost savings warrants a more detailed consideration in Phase II. In Phase II, one of the most important initial tasks would be to create and run biophysical models capable of linking green infrastructure measures with their intended outcomes. In the upper watershed, this would mean modeling the effects of thinning, prescribed fire, fuel breaks, and road decommissioning on the probability of fire as well as the costs associated with those fires. In the lower watershed, it would mean modeling the nutrient reduction potential of BMPs of different types in different locations, as has been done in the Chesapeake Bay Watershed and a few other places. Here, we made assumptions about these biophysical relationships based on the literature and expert opinion.

Another critical task in Phase II would be developing more precise and complete cost information, especially for BMPs in the lower watershed. Additional cost considerations that ought to be taken into account include transaction costs for farmers and ranchers not already familiar with particular BMPs, costs of developing and maintaining an effective nutrient trading program and land rental costs for removing crops or grazing land from production to make room for BMPs. The availability of BMPs, taking existing implementation into account, is another factor that needs much more detailed consideration in Phase II.

With biophysical modeling and more localized, precise information on costs and the availability of lands for green infrastructure investments the green-gray analysis presented here could be greatly refined to a level of accuracy needed to guide public investment decisions.

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