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Green Infrastructure Alternatives to the Northern Integrated Supply Project

A Preliminary Green-Gray Analysis

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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.

Center for Sustainable Economy (CSE) and other partners have pioneered an analytical technique for quantifying the economic and financial tradeoffs between green and gray infrastructure in three decision making contexts: (1) disaster risk reduction; (2) regulatory compliance, and (3) infrastructure investment (Talberth et al. 2013). This technique – green vs. gray analysis (GGA) – extends conventional public infrastructure analysis models used to evaluate the cost effectiveness of technological solutions like new reservoirs by factoring the unique role that wetlands, forests, riparian zones and other green infrastructure elements play in enhancing water quality and flow or achieving other environmental objectives. GGA is used to determine whether investing in these green infrastructure options is a more cost effective approach than the traditional, technological approaches (which we refer to as "gray infrastructure" throughout this report).

GGA is completed in two distinct phases. In Phase I, a preliminary analysis is conducted based on existing, publically available information. The Phase I analysis provides a rough order of magnitude[3] estimate of costs for both green and gray options and identifies key assumptions that would bolster the case for green. An example of a key assumption tested in Phase I is the assumption that a particular green infrastructure investment, say constructed wetlands, will result in a particular level of nutrient reduction in a nearby river. In Phase II, more detailed modeling is used to predict the actual level of nutrient reduction, in this case, associated with a particular investment.

In this report, CSE has completed a Phase I investigation of the potential cost savings associated with investments in green infrastructure solutions to water supply 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.

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[3] Rough order of magnitude (ROM) estimates are standard for preliminary feasibility analysis since many specific cost factors remain unknown. An estimate range of $10 - $100 per acre for a green infrastructure option is an example. In Phase I, the range can be much narrower if existing information is relatively reliable.

A warming and drying climate coupled with substantial population growth has been the impetus for the proposed Northern Integrated Supply Project (NISP) – a classic gray infrastructure solution to water supply issues. NISP is a proposed water storage and distribution project intended to supply 15 northern Front Range water partners with 40,000 acre feet of new, reliable water supplies.[4] Two new reservoirs and the canals and pipelines that bring water to and from those reservoirs form the centerpieces of NISP. Costs to construct and initiate the NISP are estimated at roughly $480 million. The Army Corps of Engineers is the lead federal agency on the project, and as of this writing, a draft environmental impact statement (DEIS) has been released and comments on that draft are being considered.

Advocates for maintaining the Cache la Poudre as a wild river warn of NISP's major environmental and economic impacts. For example, the NISP reservoirs would be supplied by increased diversions from the Cache La Poudre River, impacting the magnitude and duration of peak flows that are critical to stream and riparian habitat health, river recreation, and the businesses that rely on it (Belanger et al. 2012). These advocates argue that investments in green infrastructure solutions, including investments in conservation and efficiency, can obviate the need for NISP by reducing water demand while avoiding substantial costs over the long run. A recent report by Western Resource Advocates evaluated one approach for conservation and efficiency known as The Better Future for the Poudre River Alternative ("Better Future"). They found that meeting the 40,000 acre feet target with this alternative instead of NISP could represent a cost savings of over $200 million (Belanger et al. 2012).

Aside from water conservation and efficiency, other green infrastructure options exist for consideration to enhance water supply in the Cache La Poudre and Big Thompson watersheds. These include investments in watershed restoration activities that enhance flows – especially during the dry season – and make the watershed more resilient to fires and flooding. These are bothmajor issues for communities along the Front Range. In this analysis, we supplement the Belanger et al. (2012) analysis by conducting a Phase I GGA of a series of investments in ecologically-based thinning, road decommissioning, prescribed fire, restoration of riparian habitats, and restoration of extirpated beaver colonies as a way to contribute to increased water availability and eliminate the need for NISP. We consider this alternative to NISP both in combination with the Better Future alternative as a way to buffer against the uncertainties involved with either approach and separately..

To model these benefits in Phase I, we developed three scenarios that could unfold over the next twenty years. The first is the "gray" scenario where no additional green infrastructure investments take place and utilities and Front Range communities opt for NISP alone to meet future water demand. The second scenario is one where utilities and Front Range communities opt for a series of investments in ecologically based forest thinning, fuel breaks, road decommissioning and restoration of beaver colonies in the upper portion of the Cache la Poudre and Big Thompson watersheds to enhance flows and reduce the risk of watershed damages associated with high severity fire. The third scenario has utilities and Front Range communities opting for both the Better Future alternative as well as investments in watershed restoration described for scenario 2. We then modeled the difference in economic costs under each scenario

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[4] For an overview of the NISP, please visit: http://www.northernwater.org/WaterProjects/NISP.aspx.

over twenty years using the standard GGA. The results provide a compelling case for further investigation of the green infrastructure options to NISP. Our key findings include:

- Investing in NISP will result in a present value cost of $663 - $950 million over a 20-year period, with the range defined by the range of opportunity costs of capital rates, discount rates, and assumptions made about annual operating costs.
- A large-scale program of investments in watershed restoration would cost $73 -$296 million to implement and significantly reduce the costs associated with responding to wildfire. If successful at generating enough additional flow to offset NISP, this could represent a cost savings of over 90%. But because the flow-related benefits are less certain, these investments come with a residual risk that the NISP project would have to be built in the future to meet growing water demands.
- A large scale program of investments in watershed restoration and implementation of the Better Future alternative together would represent a present value cost of $491 – $672 million, a cost savings of up to 49% over NISP. Implementing these two options together would provide an additional buffer against uncertainty and also help meet water demands beyond 2030. In contrast, NISP is presently designed to meet projected demands only until 2030.
- The magnitude of potential cost savings associated with green infrastructure options warrants a more detailed investigation in Phase II using scientific models and better site-specific information on the availability, cost, and effectiveness of green infrastructure options to reduce demand and enhance flows.

The remainder of this report is structured as follows. In section two, we provide details of the three scenarios developed for the analysis. In section three, we report the results of the GGA for three cases per scenario: a baseline, a case more optimistic for green infrastructure, and a case more optimistic for NISP. In section four we offer concluding thoughts and suggest ways to approach the more detailed GGA analysis in a Phase II analysis.

2.0 Description of the three scenarios

In this section we describe three scenarios for meeting future water needs for Front Range communities: the NISP, watershed restoration, and watershed restoration in combination with the Better Future alternative. Details of the NISP and Better Future are summarized in brief, since they have been described in detail in other publications. Details of the watershed restoration alternative and its potential flow-related benefits are described in more depth below since it has not yet been discussed or developed for consideration.

2.1 Northern Integrated Supply Project

NISP is a proposed water storage and distribution project intended to supply 15 Northern Front Range water partners with 40,000 acre feet of new, reliable water supplies. The NISP will be managed by the Northern Colorado Water Conservancy District, a public agency created in 1937 to contract with the federal government to build the Colorado-Big Thompson Project (C-BT). The C-BT provides supplemental water to more than 640,000 acres of irrigated farm and ranch land and about 860,000 people in Northeastern Colorado. Northern Colorado Water Conservancy District is authorized by federal law to acquire and appropriate water, and to conserve, develop, and stabilize water supplies for domestic, irrigation, power, manufacturing, and other beneficial uses.

The Army Corps of Engineers is the lead agency for the project, and has published a DEIS containing project details, an overall justification for the project, and a detailed examination of its likely environmental impacts. According to the DEIS, the project will consist of a proposed Glade Reservoir with a capacity of approximately 170,000 acre-feet (AF).[5] Associated with this reservoir would be a forebay, pump station, and diversion structure and canal upgrade to convey water diverted from the Cache la Poudre River to the proposed reservoir. A pipeline connecting the proposed Glade Reservoir to the existing Horsetooth Reservoir also would be constructed. Construction of Glade Reservoir would inundate a section of U.S. 287 and require relocation of the highway. NISP would also involve construction of the Galeton Reservoir with a capacity of about 40,000 AF. Associated with this reservoir would be a forebay, pump station, and pipeline to deliver water diverted from the South Platte River. Water exchanges between the Galeton Reservoir and Glade Reservoir diversion locations are proposed to allow cross-watershed exchangs.

There are three primary justifications being offered for NISP. First, NISP will help meet a projected demand gap associated with future growth. In the South Platte Basin, this demand gap is expected to be between 36,000 and 170,000 AF by 2050 (Northern Water 2011). Secondly, the project is being justified as a way to protect farmland. In particular, “more than 60,000 acres of farmland could dry up because cities may have to buy agricultural water rights instead of using the water that will be available through NISP.” Id. Third, and related to the first, the project is being designed to meet the specific “firm” yield goals (the yield under all hydrologic conditions, including dry years) for 2050 by twelve project participants.[6] The requests for 40,000 AF of new firm yield are based on the participants’ analyses of their projected needs plus a 10 percent safety factor to account for uncertainty about future demand.

2.2 Watershed restoration

The hydrological benefits of watershed restoration activities are well established. They include beneficial effects on both flow and water quality, and ancillary benefits for ecological health, fisheries, and greater resiliency to fires, floods, and other natural disturbances (Davis 2010). Given this, one option for enhancing water supplies for Front Range communities that has not yet been analyzed in detail is investment in a package of water restoration activities designed to increase the availability of flows in the Cache la Poudre and Big Thompson watersheds enough to generate 40,000 AF of usable flow each year to meet future firm yield demands of NISP project participants. While purchase of water rights has been part of the process of considering

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[5] This overview of the project is based on the summary of the proposed action contained in the DEIS.

[6] DEIS at I-5. Firm yield is further defined in the DEIS as “[t]he annual yield that is available during a defined drought period. The defined drought period is the drought period in the hydrologic record developed for hydrologic modeling, for NISP the defined drought period is 1954, 1955, and 1956.”

alternatives to NISP, the idea of supplementing flows to accomplish the same goal of increased water availability has not been considered.

In a previous analysis, CSE and the World Resources Council (WRI) developed an ambitious but achievable portfolio of green infrastructure investments in the Cache la Poudre and Big Thompson Watersheds to reduce the risk of high severity fire and reduce the water related costs of future fires that do occur. In the context of that analysis, and through an extensive stakeholder involvement process, we developed a package of green infrastructure investments in the form of thinning unnaturally dense stands, prescribed fire, forest restoration (replanting and invasive species management), fuel breaks, and road decommissioning (Talberth et al. 2013b). These include 413,433 acres of thinning treatments and subsequent prescribed fire and restoration activities, 58,896 acres of fuel breaks, and decommissioning 1,018 miles of road (Table 1). Over a 20-year period, that analysis found those green infrastructure investments could generate up to $320 million in savings after taking costs of implementation into account.

These same measures are also likely to have a beneficial impact on river flows, though the magnitude of benefit cannot be determined without detailed scientific modeling. Nonetheless, the literature is suggestive that watershed restoration activities could make a significant contribution to meeting future water demands. For example, there have been numerous studies worldwide demonstrating that changes in forest density can cause a change in water yield. The general conclusion is that approximately 20 percent of the basal area of the vegetation must be removed before a statistically significant change in annual runoff can be detected (Bosch and Hewlett 1982; Stednick 1996).

As part of the Sierra Nevada Ecosystem Project, Marvin (1996) developed a model relating annual runoff response to timber harvest from a simple linear regression of 31 catchment experiment results from the western United States. In these catchments, increases of up to 81% were observed, but studies varied widely from 0% to this value. In the cold snow zone of the Rocky Mountains, virtually any reduction in stand density has been shown to increase snowpack accumulation and thus water yield in the spring and summer months (Troendle et al. 2010). In light of this, the thinning treatments considered by the CSE-WRI team would cover nearly 25% of the watershed areas considered, and are likely to have a measurable effect on water yield.

The decommissioning of roads, which involves removing the road footprint from the landscape, removing culverts, and restoring native vegetation has been less well researched, but also has demonstrated benefits for flows and groundwater recharge. The adverse impacts of roads are well understood. As noted by Forman and Alexander (1998) "[i]ncreased runoff associated with roads may increase the rates and extent of erosion, reduce percolation and aquifer recharge rates." Conversely, road removal enhances groundwater recharge and subsequent surface water flows. In one recent analysis, the Forest Service found that "[d]ecommissioning of roads that have altered flow patterns through increased drainage density (i.e., road ditches that intercept water and lead-out ditches that discharge concentrated ditch flow onto the forest floor) or redirected storm water runoff (i.e., roads and ditches that intersect stream courses and discharge storm water runoff directly to stream courses) would improve overall watershed hydrology, thus improving waterflow to riparian ecosystems" (USFS 2013).

Another option not considered in the CSE-WRI project but of great interest to watershed restoration advocates throughout the West is the reintroduction of beaver colonies. The effects of dam-building beavers on water storage and water quality enhancement can be superior to engineered solutions and have been proposed as a cost-effective strategy to reach ecosystem restoration goals (Albert and Trimble 2000; McKinstry et al. 2001; McKinstry and Anderson 2002; Luce and Holden 2009). Restoring their populations holds the potential to significantly improve a range of natural systems and affect water availability, water quality, instream flows and habitat, and reduce costs for water storage, habitat restoration, and water quality treatment (Buckley et al. 2011).

Beavers have long been noted for the water stored behind their dam complexes (Naiman et al. 1988; Baker and Cade 1995; Westbrook et al. 2006; Luce and Holden 2009). In areas where dam building beavers are numerous, as much as 30% or 40% of the volume of water in a 3rd to 4th order stream network may reside behind their dams (Duncan 1984; Naiman et al. 1988). This "stored" water increases the surface water extent within the watershed and contributes to groundwater stores, keeping the water table well charged (Westbrook et al. 2006).

The effect of beaver ponds and the well charged water table they create on summer-time surface flows is positive. Streams have higher summertime "base" flows (or shift from intermittent to perennial streamflow) following re-establishment of beavers (Yeager and Hill 1954; Rutherford 1955; and Parker 1986). While the magnitude of expected increase will depend on the hydrology and geology of the region and the number of beaver colonies the watershed can support, evidence strongly supports an increase in seasonal water yield following beaver establishment in a watershed.

In the Hangman (Latah) Creek Watershed in Washington and Idaho, Parrish and Hall (2010) concluded that beaver re-introduction "holds enormous potential in increasing water storage and late summer flows." They found that beavers could supplement late summer flows by over 4%.[7] In addition to their effect on surface water, beaver dams affect groundwater by increasing recharge and retention.[8] Research suggests that beaver dams can hold up 30–60 percent of base flow and discharge it later (Kay 1994). Because of these beneficial effects on flows, especially during the dry season, a beaver reintroduction strategy is clearly one that bears consideration as an alternative to gray infrastructure options like NISP.

A successful beaver colony reintroduction program has two major steps. The first is restoration of riparian areas to create habitat that beaver are likely to use. The second is the reintroduction of and monitoring of beaver colonies. To scope out the potential magnitude of a beaver colony reintroduction program, CSE and Geos Institute replicated the analysis conducted by Bird et al. (2013). There were three major steps. First, we evaluated streamside areas to determine currently suitable versus potential beaver habitat in the two watersheds. The principle habitat requirements

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[7] Low flows of 10 cubic feet per second (cfs) are common for the Hangman Creek Watershed. A restoration strategy along 37 stream miles with 5 beaver dams per mile could supplement flows by 0.41 cfs, or 4.1%.

[8] See, for example: Lowry, M. 1993. *Groundwater Elevations and Temperature Adjacent to a Beaver Pond in Central Oregon*. Dissertation submitted to Oregon State University; Pollock, M., M. Heim, and D. Werner. 2003. "Hydrologic and geomorphic effects of beaver dams and their influence on fishes." *American Fisheries Society Symposium*. 1-21.

for dam building beaver are low order streams with low slope gradients and sufficient food. In order to determine the location of potential and suitable beaver habitat, we classified stream miles according to five different factors or tiers that describe the likelihood of beaver using those reaches. The final suitability tiers were intersected with the Protected Areas Database (PAD) in order to quantify the miles in each suitability tier for each landowner type. Our assumption is that beaver reintroduction would only occur on stream reaches that were already in some kind of protected area designation such as national parks, public lands, or private lands with conservation easements.

The final program design assumes that tier 1 and 2 stream miles are sufficient for reintroduction of colonies, at a density of roughly one colony per stream mile. We identified 533.6 miles of tier 1 and 2 streams within the Cache la Poudre and Big Thompson Watersheds. We also assume that tier 3, 4, and 5 stream miles would first require at least some level of investment in stream restoration, and then subsequent colony reintroduction ten years hence. There were 264.8 miles of these streams in our analysis area. So for purposes of this Phase I analysis, we assume that the final program consists of a combination of reintroduction and riparian restoration along 798.4 stream miles (Table 1).

The mean annual flow for the Cache la Poudre River and Big Thompson Creek watersheds are 300,000 AF and 123,000 AF, respectively. Thus, to be successful in enhancing flows, the watershed restoration strategies under a green infrastructure alternative would have to supplement native flows by roughly 10%. While we cannot yet determine whether this is feasible, the literature suggests that the combined effects of an ambitious package of investments in ecoloigcally appropriate forest thinning, road decommissioning, riparian zone restoration and beaver reintroduction could meet or surpass this goal. As such, this option warrants careful consideration as an alternative to NISP.

Table 1:
Watershed Restoration Scenario in the Cache la Poudre and Big Thompson Basins

Activity	Scope
Thinning, prescribed fire and restoration (acres)	413,433
Fuel breaks (acres)	58,896
Road decommissioning (miles)	1,018
Beaver colony reintroduction (stream miles)	798.4
Beaver habitat restoration (stream miles)	264.8

2.3 Watershed restoration plus the Better Future alternative

The third alternative in our GGA is a combination of watershed restoration and implementation of the Better Future Alternative. Better Future is an alternative to NISP first developed by the Save the Poudre Coalition and Western Resource Advocates (WRA) in 2008 but recently updated to incorporate current Colorado State Demography Office population projections, revised NISP participant demands and supplies from a 2011 report by Harvey Economics, data from the Colorado 2010 Statewide Water Supply Initiative, and other recent reports (Belanger et al. 2012). According to WRA, Better Future would provide water supplies sufficient to meet and exceed NISP participants' water demands through 2060 while maintaining flows critical to aquatic and riparian environments and recreational opportunities in the Cache la Poudre River.

By 2030, the Better Future Alternative would proposes to purchase water rights from agriculture to accommodate growth (7,360 AF), conserve water (6,401 AF), reuse water (3,935 AF), and develop cooperative agreements with agriculture (10,000 AF). Additional water rights purchasing and other measures implemented after 2030 would bring the total firm yield up to 60,550 AF by 2060. For purposes of this analysis, we limit consideration to just those measures implemented before 2030, and do not include the conditional (optional) measure – the Windy Gap Firming Project – discussed by WRA.

The rational for an alternative that combines both watershed restoration and the Better Future Alternative is the uncertainty involved with both. While the yield-related benefits of watershed restoration are well documented in general, they will remain quite uncertain in the Cache la Poudre and Big Thompson watersheds until more site-specific modeling is completed, as do many other details such as how enhanced flows in either drainage would translate into firm yield demands for each NISP participant. And while there is no question that the total AF targeted by Better Future Alternative is more than enough to offset NISP, there are many aspects of each measure within the alternative that need more refinement to be feasible. For example, technical issues, legal challenges, and existing reluctance on the part of municipalities and irrigators all need to be overcome before cooperative agreements with agriculture become a reality (Belanger et al. 2012).

3.0 Green Gray Analysis

In this section, we take the data presented for each scenario and complete a preliminary GGA using standard modeling techniques synthesized by Talberth et al. (2013a), but based on standard public infrastructure investment analysis. The general approach involves using a spreadsheet-based model to compare the present value costs of both green and gray options taking into consideration capital or up front costs of the 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. 2013a). This GGA is intended to serve the second purpose – identifying the least cost manner to provide public water supply as demand rises and supply becomes increasingly uncertain in the face of climate change.

3.1 Costs of the Northern Integrated Supply Project

Costs of constructing and operating NISP fall into three major categories: (a) initial capital costs associated with construction of the water storage and supply network; (b) annual operating costs, including energy required to operate pumps, and (c) the opportunity costs of capital. In the context of GGA for water resource projects, these costs are calculated using the standard "two stage" discounting method recommended by the Environmental Protection Agency.[9] The method involves annualizing capital costs over an appropriate analysis period, incorporating the opportunity costs of capital (OCC), adding to those annualized values yearly operations and maintenance costs, and then discounting the entire cost stream back to the present at the social discount rate. EPA recommends the use of 7% as the OCC, and 3% as the social discount rate.

A key component of this process is incorporating the OCC, which represents the investment earnings foregone as capital is tied up in a particular project as opposed to being available for use in alternative investments. In this sense, the OCC is the rental rate for the capital resources utilized. As EPA notes, "[i]nvesting ties up capital in the ownership of the asset. By not allowing these funds to flow elsewhere, the capital is 'rented' in the form of this particular asset."[10] Including OCC provides a much better sense of the overall capital costs of the project based purely on simple discounting of construction, land acquisition, and equipment costs.

As an illustration, the Bureau of Reclamation's economic analysis for the Navajo-Gallup Water Supply project estimates up front capital costs to be roughly $370 million for a series of water diversions from the San Juan River to the Navajo nation.[11] Using a low OCC of 4% translates into an annualized capital cost stream of $18.7 million per year over a 40-year period. By this method, the undiscounted total capital cost for the project is estimated to be $748 million – over double the baseline capital cost estimate.

In this analysis, we apply the EPA's two stage discounting procedure to the NISP to develop cost estimates for three distinct cases: Baseline, Low Gray, and Low Green (Table 2). In the Baseline case, we set the OCC to 7% and discount rate to 3% as per EPA guidance. The project period is set at 20 years, which is roughly the time frame needed for NISP water to be available at the anticipated quantity of 40,000 AF per year. Capital costs for the ten major capital components were taken from the DEIS, but updated to current ($2013) dollars.[12] In the DEIS, the Army Corps of Engineers estimated annual operating costs to be roughly one-half a percent of capital costs, or roughly $2.78 million per year in current dollars. The DEIS also estimates $40/AF for pumping 124,300 acre feet each year. This translates into $5.77 million in costs in current dollars. The total cost for the NISP Baseline case is roughly $908 million in present value terms (Table 2).

In the Low Gray case, a case more optimistic for gray infrastructure, we lower the opportunity cost of capital to 5% and raise the discount rate to the same level. This results in a substantially lower total cost estimate of roughly $663 million. In the Low Green case, one more optimistic for green infrastructure, we restore the OCC and discount rate to 7% and 3% respectively, and raise the cost estimate for annual operating costs from 0.5 to 1.0% of capital costs. This seems well justified from the literature. Capital costs for large water projects can range widely, but a review of dozens of these projects conducted for CSE's Front Range project with WRI and CCC

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[9] An overview of the two-stage procedure is available from EPA online at: http://www.epa.gov/ttnecas1/econdata/Rmanual2/8.3.html.

[10] Id.

[11] FEIS for the Navajo-Gallup Water Supply Project, Appendix A: Technical Memorandum, Chapter 9, The Unit Cost of Project Water. Available online at: http://www.usbr.gov/uc/envdocs/eis/navgallup/FEIS/index.html.

[12] DEIS at 2-45 (Table 2-6: NISP Estimated Action Alternative Costs).

(Talberth 2013b) reported an average of roughly 1%, but with values as high as 9%. In the Navajo-Gallup Water Supply Project, the lowest end of the operating cost range was 1.8% of capital costs – over three times the Baseline NISP estimate. Setting operations and maintenance costs at 1% rather than 0.5% of capital costs raises annual costs from $2.78 to $5.56 million, and the total present value cost of NISP to nearly $950 million.

Table 2
Costs of the Northern Integrated Supply Project

Project element	Baseline case (2013 $millions)	Low Gray case (2013 $millions)	Low Green case (2013 $millions)
Annualized capital costs			
Glade reservoir	$17.19	$14.61	$17.19
Land acquisition for Glade reservoir	$1.09	$0.93	$1.09
Glade reservoir forebay	$0.33	$0.28	$0.33
Glade pump station	$3.61	$3.07	$3.61
U.S. 287 realignment	$4.33	$3.68	$4.33
Glade to Horsetooth pipeline	$1.53	$1.30	$1.53
PV canal upgrade and Glade diversion	$2.85	$2.42	$2.85
Galeton reservoir	$5.26	$4.47	$5.26
SPWCP	$10.62	$9.03	$10.62
Carter pipeline	$5.69	$4.84	$5.69
Total annualized capital costs	$52.50	$44.63	$52.50
Annual operations and maintenance	$2.78	$2.78	$5.56
Annual pumping costs	$5.77	$5.77	$5.77
Total annual costs	$61.05	$53.18	$63.83
Present value total costs over 20 years	**$908.31**	**$662.76**	**$949.64**

3.2 Costs of the watershed restoration alternative

Unlike NISP, the watershed restoration alternative consists of a series of annual expenditures with no up front or capital investment requirements. Thus, modeling costs is relatively straightforward, and does not include the first stage of the two-stage discounting procedure. For this analysis, we assume that watershed restoration activities are carried out throughout the 20-year analysis period with the goal of having at least 40,000 AF of enhanced flows generated by the end of that period. So each year, accomplishments are assumed to represent 1/20 of the total acres or miles reported in Table 1. Multiplying these annual accomplishment values by unit costs gives the expected cost per year. The present value of the watershed restoration portfolio is simply the 20-year cost stream discounted back to the present at case-specific discount rates.

As with NISP, we model three cases – Baseline, Low Gray, and Low Green. For the Baseline case, we use the mean unit cost values for each activity reported in Table 3 and a discount rate of 3%. For thinning, fuel breaks, and road decommissioning we use mean unit cost values reported by Talberth et al. (2013b). For beaver colony reintroduction, the mean cost values were based on a range of $350 - $1,500 per colony based on personal interviews with experts.[13] For the mean cost of restoration of beaver habitat, we incorporate the range of values estimated by Bair (2000), but updated to current dollars.

Under the Baseline case, we estimate total present value costs of the watershed restoration alternative to be roughly $207 million (Table 4). In the Low Gray case, a scenario more favorable to gray, we use the high end of the unit cost ranges reported in Table 3, and a discount rate of 5%. The total present value costs rise to over $317 million. In the Low Green case, we incorporate the low end of the unit cost ranges reported in Table 3 and use a discount rate of 3%. Present value costs fall to $78 million. The wide range of cost estimates here reflects the wide range of unit costs for each element. In Phase II, a more detailed scope of activities under this alternative would help generate more precise unit cost values.

Table 3:
Watershed Restoration Unit 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
Beaver colony reintroduction – colony only (per colony)	$350-$1,500	$925.00
Beaver colony reintroduction – habitat restoration (per mile)	$86,803-$480,849	$175,115[14]

Table 4:
Costs of the Watershed Restoration Alternative

Activity	Baseline case (2013 $millions)	Low gray case ($2013 millions)	Low green case ($2013 millions)
Annual costs – watershed restoration			
Thinning, prescribed fire and restoration	$9.30	$16.25	$2.36
Fuel breaks	$2.13	$2.65	$1.62
Road decommissioning	$0.09	$0.13	$0.06
Road decommissioning annual maintenance	$0.01	$0.01	$0.01
Beaver colony reintroduction	$0.04	$0.06	$0.01
Beaver habitat restoration	$2.32	$6.37	$1.15
Total annual costs	$13.89	$25.46	$5.20
Present value total costs over 20 years	**$206.70**	**$317.33**	**$77.43**

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[13] Bryan Bird, personal communication with Blagg, D.J. and Parish, A, 10-29-13.

[14] Weighted mean.

3.3 Costs of watershed restoration plus the Better Future alternative (WR + BF)

Costs of the Better Future lternative were estimated by Belanger et al. (2012), but with a method that departs from the analysis here in two ways. First, that analysis was based on a single discounting of costs rather than the two-stage discounting procedure recommended by EPA that accounts for the opportunity costs of capital. Under the Better Future alternative, expenditures for water rights, active conservation, and reuse are one-time capital costs that warrant a two-stage discounting under GGA methods. Secondly, that report assumed a more complex staged implementation scenario running through 2060 – for example, with the bulk of active water conservation savings not being realized until after 2030. Here, we just consider measures implemented through 2030, but front load active conservation enough to meet the 40,000 AF target by that date.

Given this, our analysis assumes the following activities implemented through 2030: (1) water rights purchasing of 7,360 AF, as per the WRA analysis through 2030; (2) active conservation of 16,800 AF, which is the WRA long term goal by 2060; (3) reuse systems in place by 2030 to handle another 3,935 AF as per WRA, and (4) cooperative agreement with agriculture to secure another 11,905 AF, a slight increase from the WRA assumption.[15] As for unit costs, we adopt the WRA assumptions for each updated to $2013, but include ranges for reuse and cooperative agreements in order to have substitute values for the Low Green scenario. The final unit cost assumptions include $11,414 per AF for water rights, $8,351 per AF for active conservation, $7,495 - $13,777 per AF for reuse, and $325 - $418 per AF for cooperative agreements.

As before, three scenarios were modeled and then added to the watershed restoration costs to get the full present value costs of implementing the WR + BF alternative. In the Baseline case, we set OCC to 7%, the discount rate to 3%, used upper bound estimates for BF costs, and mean values for WR costs. In the Low Gray case, we set both the OCC and discount rate to 5%, and use upper bound figures for all green infrastructure elements. In the Low Green Case, we use 7% for OCC, 3% for the discount rate, and lower bound unit cost estimates for all green infrastructure elements. Costs of the BF alternative by itself are estimated to range from $414 to $465 million in present value terms (Table 5), and represent a cost savings of $450 - $531 million over NISP. Combined with the watershed restoration alternative, total costs range from $491 to $672 million, and represent a cost savings of up to $458 million over NISP in the Low Green case to essentially breaking even in the Low Gray case.

Figure 1 reports total present value of costs for the NISP, the WR alternative alone, and for the watershed restoration alternative plus Better Future for the three modeled cases: Baseline, Low Gray, and Low Green. Under both Baseline and Low Green cases, there is significant potential for cost savings, especially if the watershed restoration alternative can be successful on its own. Even if combined with Better Future, the cost savings under both these cases are substantial. Only under the Low Gray case does the combined watershed restoration and Better Future package look less economically feasible. Either way the message is clear: green infrastructure could represent a huge cost savings relative to NISP for enhancing water supply to the

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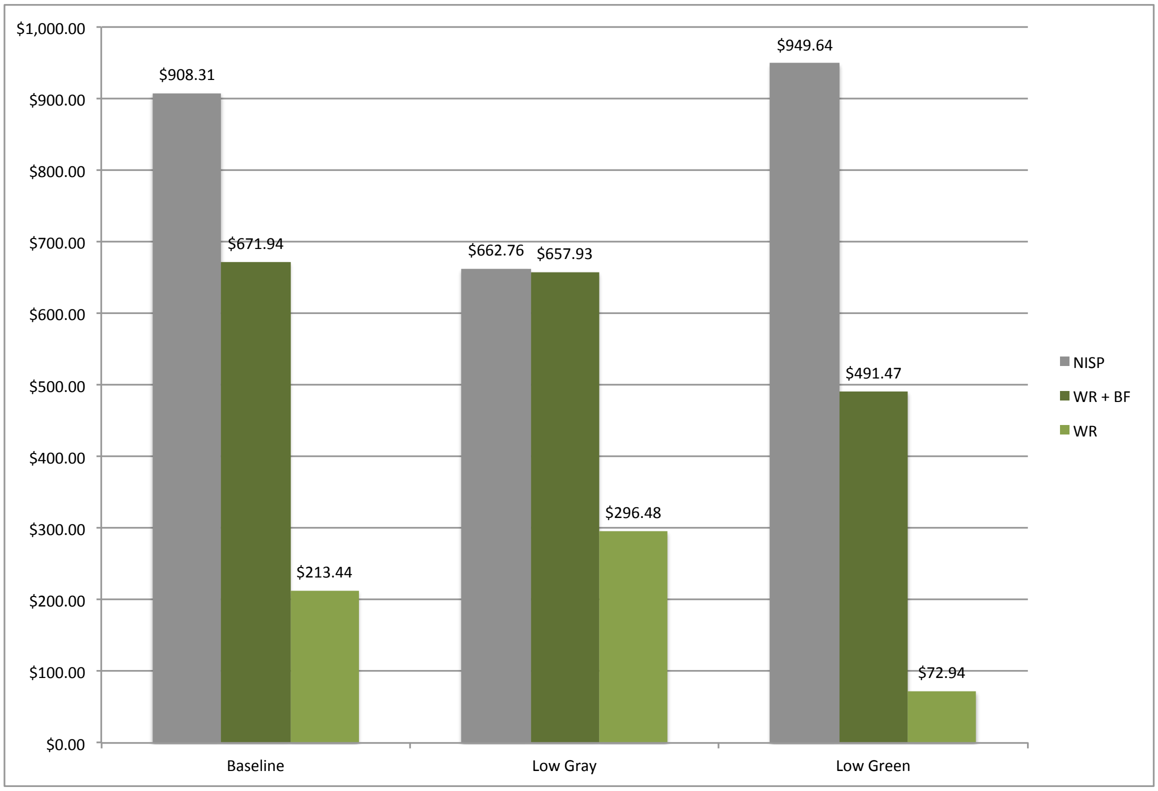
[15] Since this was the most speculative element, we assumed that it could generate somewhat more than the 10,000 AF goal and thereby ensure that the four BF measures add up to the required 40,000 AF target.

communities along the northern Front Range of Colorado, and warrants a more in-depth analysis in a Phase II study.

Table 5:
Costs of Watershed Restoration Plus Better Future Alternative

Activity	Baseline case (2013 $millions)	Low gray case ($2013 millions)	Low green case ($2013 millions)
<u>Annual costs – watershed restoration</u>			
Thinning, prescribed fire and restoration	$9.30	$16.25	$2.36
Fuel breaks	$2.13	$2.65	$1.62
Road decommissioning	$0.09	$0.13	$0.06
Road decommissioning annual maintenance	$0.01	$0.01	$0.01
Beaver colony reintroduction	$0.04	$0.06	$0.01
Beaver habitat restoration	$2.32	$6.37	$1.15
Total annual costs watershed restoration	$13.89	$25.46	$5.20
Present value total costs over 20 years	**$206.70**	**$317.33**	**$77.43**
Total annual costs Better Future	$31.27	$27.33	$27.83
Present value total costs over 20 years	**$465.24**	**$340.60**	**$414.04**
Present value combined total costs	**$671.94**	**$657.93**	**$491.47**

Figure 1:
Cost Comparisons – NISP, Watershed Restoration Plus Better Future (WF + BF)
and Watershed Restoration Alone (WF)
(Present Value $2013 Millions)



4.0 Concluding Thoughts and Suggested Refinements for the Phase II Analysis

Although our analysis is preliminary, and based on many assumptions that need to be revisited in Phase II, our preliminary green-gray results for alternatives to the NISP are promising. Our analysis has four major conclusions:

1. An ambitious, yet achievable portfolio of watershed restoration investments could enhance native river flows in the Cache la Poudre and Big Thompson watersheds and potentially offset the need for NISP at a fraction of its cost. But the precise impacts of the green infrastructure options considered here such as thinning and beaver colony reintroduction needs to be modeled before any conclusions can be drawn about likely effects on flow.
2. The feasibility of green infrastructure investments as an alternative to NISP become more compelling when combined with the conservation and efficiency measures contemplated by the Better Future alternative since the potential flow-related benefits of watershed restoration are relatively uncertain at this time.
3. Watershed restoration activities coupled with Better Future presents a feasible alternative to NISP that is significantly more certain to meet future firm yield demands by NISP participants – a combined alternative that could represent cost savings of hundreds of millions of dollars.
4. 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 scientific models capable of linking ecologically-based thinning, road decommissioning, and reintroduction of beaver colonies with increases in the quantity and timing of river flows. In particular, it will be critical to develop the likely, optimistic, and pessimistic bounds of these flow impacts from forest work and beaver reintroduction to ascertain whether or not the 40,000 AF flow target could be met even in part through these activities. Those results will help refine the scope of the Phase II economic analysis by establishing the most optimal mix of conservation practices (water rights purchase, etc.) and watershed restoration needed to offset the need for NISP.

Another key task would be to develop a more targeted and precise menu of restoration investments that would represent the biggest bang for the buck in terms of flow. Another critical task in Phase II would be developing more accurate and complete cost information, especially for watershed restoration measures. For some green infrastructure activities, such as water reuse or beaver habitat restoration, unit costs varied by as much as a factor of 6 and as a result the final tallies for green infrastructure costs across the three cases were equally divergent.

With scientific modeling and more localized, precise information on costs as well a more detailed analysis of the availability of lands and streams for watershed restoration activities 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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