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**Economic Benefits of Instream Flow Protection**
**For Middle Creek (Stream 2003), Alaska**

Prepared for Cook Inletkeeper

By

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## 1.0 Key points

- In adjudicating Chuitna Citizens Coalition's applications to reserve water in Middle Creek (Stream 2003), the Alaska Department of Natural Resources (ADNR) must consider a comprehensive menu of benefits to all Alaskans.
- The framework of ecosystem services is the standard decision-making framework for federal and state public agencies tasked with assigning values to intact natural resources.
- Ecosystem service benefits of the Middle Creek watershed are likely to be in the range of $55.4 million to $134.2 million each year, or a present value of $1.4 billion to $3.5 billion over 50 years.
- Instream flow benefits are a sub-component of ecosystem services provided by Middle Creek. The literature on instream flow benefits per acre-foot suggests an annual value of instream flow on Middle Creek to be in the order of $7.1 million to $17.0 million each year, or a present value of $183.4 million to $436.6 million over 50 years.
- In its cursory evaluation of benefits, ADNR considered just one small value – the market value of coho – and excluded all other ecosystem services. Moreover, ADNR underestimated this one benefit by a factor of ten or more by erroneously using exvessel prices as a measure of value and using an unrealistically low figure for survival rates.
- Using market prices rather than exvessel prices, the value of adult coho in Middle Creek is likely to range between $129,292 and $150,808 per year, a present value of $3.3 million to $3.9 million over 50 years.
- The value of sportfishing associated with Middle Creek's fishery was ignored by ADNR, but is likely to range between $403,210 and $470,310 per year, a present value of $10.4 million to $12.1 million over 50 years.
- ADNR must also consider the avoided costs associated with development of the Chuitna coal mine. Development of this mine would generate economic losses to the public of between $58.78 billion and $78.01 billion. Granting CCC's application would avoid this loss.

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## 2.0 Background

In 2009, the Chuitna Citizens Coalition (CCC) filed applications to reserve water within the main, middle, and lower reaches of Middle Creek (also known as Stream 2003), near Beluga, Alaska, for the purpose of maintaining specified instream flow rates to protect fish and wildlife habitat, migration, and propagation.[2] The Alaska Department of Natural Resources (ADNR) is adjudicating these applications. The applications were filed pursuant to Alaska's Water Use Act, which, in pertinent part, requires ADNR to issue the instream flow reservation if (1) the rights of prior appropriators will not be affected by the reservation; (2) the applicant has demonstrated that a need exists for the reservation; (3) there is unappropriated water in the stream or body of water sufficient for the reservation; and (4) the proposed reservation is in the public interest.[3]

As part of the public interest determination, ADNR prepared a brief report quantifying one specific economic benefit that would arise in association with a grant of the application – the ex-vessel present value of adult coho salmon that will inhabit the stream over the next 25 years.[4] ADNR did not include in the administrative record any other information on additional economic benefits associated with the proposal. Nor did ADNR consider the costs avoided by granting the applications, namely, the wide range of public costs that will be incurred if the Chuitna coal mine is developed, such as the social costs of carbon emissions. Granting instream flow protections for Middle Creek will protect over a dozen miles of salmon bearing stream that would otherwise be destroyed by the proposed coal strip mine. This report provides a more comprehensive overview of the numerous economic benefits associated with Middle Creek in its natural state, as well as a discussion of avoided costs associated with preclusion of the Chuitna Coal Strip Mine.

## 3.0 The public interest standard of review

ADNR's public interest determination must rest on an evaluation of eight distinct factors enumerated by Alaska's Water Use Act: "(1) the benefit to the applicant resulting from the proposed appropriation; (2) the effect of the economic activity resulting from the proposed appropriation; (3) the effect on fish and game resources and on public recreational opportunities; (4) the effect on public health; (5) the effect of loss of alternate uses of water that might be made within a reasonable time if not precluded or hindered by the proposed appropriation; (6) harm to other persons resulting from the proposed appropriation; (7) the intent and ability of the applicant to complete the appropriation, and (8) the effect upon access to navigable or public water."[5]

From an economics standpoint, this is a fairly comprehensive list. It includes costs and benefits not only enjoyed or incurred by the applicant, but by all Alaskans. Everyone's costs and benefits

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[2] Alaska DNR's Notice of Applications for Reservation of Water in Middle Creek can be reviewed online at: https://aws.state.ak.us/OnlinePublicNotices/Notices/View.aspx?id=175666.
[3] Alaska Statutes (AS) 46.15.145(c); 11 Alaska Administrative Code (AAC) 93.146(a).
[4] Sager, Kim. 2015. Memorandum on the economic values of Stream 2003. Alaska Department of Natural Resource, Water Resources Section.
[5] AS 46.15.080(b).

matter, and ADNR's duty is to be as comprehensive as possible.[6] In this matter, the costs and benefits relevant to the public interest standard can be distilled into two broad categories: ecosystem service benefits and opportunity costs associated with preclusion of the Chuitna mine.

## 4.0 Duty to quantify ecosystem service benefits

In 1997, Gretchen Daily is credited with having offered the first formal definition of ecosystem services: "[e]cosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life."[7] The most ubiquitous definition of ecosystem services used today is a more generalized one: "[e]cosystem services are the benefits people obtain from ecosystems."[8] The concept of ecosystem services thus encompasses all of the benefit categories enumerated in the public interest standard set forth in AS 46.15.080(b).

### 4.1 Types of ecosystem services present in Middle Creek

Ecosystem services fall into three broad categories:

1. Provisioning services, which refer to the food, fuel, fiber, and clean water that ecosystems provide.
2. Regulating services, which refer to specific ecosystem processes for which people are willing to pay. Examples include pollination, storm protection, climate regulation, and water regulation.
3. Cultural services, which refer to the benefits ecosystems confer that do not directly relate to our physical health or material wellbeing. Examples include recreation, aesthetic, spiritual, existence, and option "values." Whereas the first two of these are experiential, the latter "non-use" values depend simply on the continued survival of the ecosystem and its attributes.[9]

The natural ecosystems of the Middle Creek watershed at issue in the adjudication of CCC's application include the creek, adjacent riparian buffers, wetlands, swamps, fen, scrub, meadow and forest habitats within its drainage.[10] Middle Creek is a 2nd-order stream draining 9,126 acres, is approximately 16.4 feet wide, and enters the Chuitna River approximately 11.2 miles upstream from Cook Inlet. The mean annual discharge is 33.90 cubic feet per second (cfs) and

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[6] Boardman, Anthony E., David H. Greenberg, Adrian R. Vining and David L. Weimer. 2001. Cost Benefit Analysis: Concepts and Practice. Upper Saddle River, NJ: Prentice Hall.
[7] Daily, Gretchen C., Ed. 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Washington, D.C.: Island Press.
[8] Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.
[9] Council on Environmental Quality (CEQ). 2014. Updated Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies. Chapter III: Interagency Guidelines. Available online at: https://www.whitehouse.gov/administration/eop/ceq/initiatives/PandG.
[10] A grant of CCC's application will alter the area affected by the Chuitna Coal Mine, and thus increase protection for all these ecosystem types throughout the Middle Creek watershed.

the stream is18.6 miles long.[11] Vegetation profiles of the proposed Chuitna coal mine area (which encompasses an eleven mile segment of Middle Creek) can be used as a basis for approximating the distribution of vegetation communities throughout the entire watershed.[12] For purposes of ecosystem service valuation, it is most useful to convert vegetation inventories into the categories used in the National Land Cover Dataset (NLCD) maintained by the US Geological Survey.[13] The NLCD is the standard used in many ecosystem service studies. The result of this exercise is reported in Table 1, below. Wetlands constitute, by far, the most prominent land cover type, followed by mixed (spruce-birch) forest, alder scrub, and fireweed meadows.

**Table 1**
**Approximate Land Cover Acreage for**
**Middle Creek (Stream 2003) Watershed**

| Land cover type | Acres | Percent |
|---|---|---|
| Mixed forest | 3,292.76 | 36.08% |
| Coniferous forest | 72.64 | 0.80% |
| Deciduous forest | 59.71 | 0.65% |
| Shrub/scrub | 954.29 | 10.46% |
| Riparian buffer | 451.00 | 4.94% |
| River | 37.00 | 0.41% |
| Meadows | 833.89 | 9.14% |
| Wetlands | 3,424.71 | 37.53% |
| *Total* | 9,126 | 100% |

Throughout the Chuitna watershed including Middle Creek, these land cover types provide a wide range of ecosystem goods and services valuable to residents of the Native village of Tyonek and those who visit from other parts of Alaska and beyond.[14] In terms of provisioning services, the Chuitna watershed supports subsistence and personal-use harvesting of fish, game, and berries. Chinook and coho salmon are the most important fish species caught; however, rainbow trout, steelhead, and Dolly Varden are taken in lesser numbers. Moose, brown bear, and black bear hunts are significant to residents and are the primary game mammals harvested for food. Other important game species include both migratory and upland birds. Pelts from beaver, river

[11] These attributes of Middle Creek are taken from Nemeth, M, J., A. M. Baker, B. C. Williams, S. W. Raborn, J. T. Priest, and S. T. Crawford. 2010. Movement and abundance of freshwater fish in the Chuit River, Alaska, May through July, 2009. Annual report prepared by LGL Alaska Research Associates, Inc., Anchorage, Alaska for PacRim Coal, L.P. 86 p.

[12] HDR Alaska, Inc. 2007. Baseline Report for Vegetation and Wetlands. Cheyenne, WY: Mine Engineers, Inc. Acreages for river and riparian buffers were estimated based on Nemeth et al. 2010 and the assumption of a 100 foot riparian buffer on either side of the creek.

[13] The National Land Cover Database for Alaska is available online at: http://www.mrlc.gov/nlcd11_data.php.

[14] The description of existing uses is based on Oasis Environmental Inc. 2006. Land Use Baseline Summary Report for the Chuitna Coal Project. Anchorage, AK: DRven Corporation.

otter, lynx, wolverine, and marten are sold in local markets. Most Tyonek residents use wild plants and berries, and these represent "the highest use level of any wild resource category."[15]

In terms of regulating services, Middle Creek's remote fish stocks also help maintain the stability of fisheries throughout the region due to what is known as the "portfolio effect." According to Schindler et al. (2010), "[o]ne of the most pervasive themes in ecology is that biological diversity stabilizes ecosystem processes and the services they provide to society, a concept that has become a common argument for biodiversity conservation. Species-rich communities are thought to produce more temporally stable ecosystem services because of the complementary or independent dynamics among species that perform similar ecosystem functions. Such variance dampening within communities is referred to as a portfolio effect and is analogous to the effects of asset diversity on the stability of financial portfolios."[16] Another provisioning service supported by Middle Creek's salmon fishery is its role in depositing marine derived nutrients (MDN) into riverine systems. These MDN's play a major role in shaping ecosystem functions and the growth and condition of aquatic, riparian and terrestrial flora and fauna.[17]

In terms of cultural services, the Chuitna watershed supports an important sport fishery, primarily for Chinook and coho salmon. There are several local outfitting businesses and charters that "take advantage of the pristine environment and low fishing pressure" on the Chuitna River.[18] Other important recreational uses include snow-machining, berry picking, camping, swimming, water skiing, and hiking. The pristine environment of the Middle Creek watershed also provides intrinsic, or non-use values held by all Alaskans. For example, by applying research findings from Pacific Northwest rivers to salmon escapement counts for rivers and streams in the Upper Cook Inlet area, ECONorthwest estimated that Alaska's annual marginal non-use willingness to pay for a Upper Cook inlet salmon to be $3.98 (2010 dollars) and the total annual non-use economic benefit of the entire Upper Cook Inlet salmon fishery to be approximately $280 million per year, aggregated across Alaska's total population.[19]

4.2 Ecosystem service valuation and agency decision-making

The duty to quantify ecosystem service effects in natural resource decision-making was recently reiterated and refined in a process led by the Council on Environmental Quality (CEQ) and

[15] Stanek, Ronald T., Davin L. Holen and Crystal Wassillie. 2007. Harvest and uses of wild resources in Tyonek and Beluga, Alaska, 2005-2006. Technical Paper No. 321. Juneau, AK: Alaska Department of Fish and Game, Division of Subsistence.
[16] Schindler, Daniel E., Ray Hilborn, Brandon Chasco, Christopher P. Boatright, Thomas P. Quinn, Lauren A. Rogers and Michael S. Webster. 2010. "Population diversity and the portfolio effect in an exploited species." Nature 465, 609-612.
[17] Rinella, D. J., M. S. Wipfli, C. M. Walker, C. A. Stricker, and R. A. Heintz. 2013. "Seasonal persistence of marine-derived nutrients in south-central Alaskan salmon streams." Ecosphere 4(10):122. http://dx.doi.org/10.1890/ ES13-00112.1
[18] Oasis Environmental, 2006, Note 11.
[19] Helvoigt, Ted L., Tobias Schwoerer and Diane Charlton. 2010. Economic Analysis of the Chuitna Watershed & Cook Inlet. Portland, OR: ECONorthwest.

seven federal Departments and agencies.[20] The end result was a set of Principles, Requirements, and Guidelines (PR&G) for all federal agencies whose decisions affect water resources.[21] The PR&G recognizes that "[r]educed service flows over time amount to costs, and increased service flows over time amount to benefits."[22] A complete accounting identifies impacted services, their value, and trends over time. The PR&G also sets the standard for consideration of ecosystem services by state-level agencies that participate with these federal Departments and agencies in water resource related decision-making. This includes decisions related to the Chuitna coal mine, which involves several federal agencies, ADNR and other state agencies.[23]

The importance of ecosystem service valuation has been recognized by the State of Alaska. For example, the Alaska Department of Environmental Conservation endorses ecosystem service valuation in assessing the value of damaged natural resources and the compensation needed to "to make the environment and public whole following a discharge of oil or hazardous materials."[24] In particular, "[c]ompensation can be monetary payments for injury to, destruction of, or loss of natural or cultural resources, and the value of the lost services provided by those resources."[25]

The Alaska Department of Fish and Game regularly evaluates the economic value associated with its management programs, and uses peer reviewed methods of ecosystem service valuation to quantify the economic benefits associated with hunting and wildlife viewing trips. For example, in its 2011 evaluation, the ADFG used the contingent valuation method to determine "the amount households would have been willing to pay for wildlife-related goods and services beyond what they actually paid. This method has been employed for decades and natural resource economists generally agree that contingent valuation can yield a reliable estimate of what the public is willing to pay for wildlife-related goods and services."[26]

## 5.0 Methods for ecosystem service valuation are readily available to ADNR

Over the past three decades economists have developed a wide range of methods for assigning monetary values to ecosystem services. All of these methods are available to ADNR for use in the public interest evaluation for Middle Creek. The choice of method depends upon the general type of ecosystem service (provisioning, regulating, cultural) whether the service provides direct or indirect benefits to those affected and whether or not economic value is associated with use of the ecosystem or associated with its non-use values.

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[20] These include: Department of the Interior, Department of Agriculture, Department of Commerce, Environmental Protection Agency, Army Corps of Engineers, Federal Emergency Management Agency and Tennessee Valley Authority.
[21] CEQ, 2014, Note 7.
[22] Id.
[23] Lead and cooperating agencies are listed here: http://www.chuitnaseis.com/links.html.
[24] Alaska Department of Environmental Conservation (ADEC). Fact Sheet: State Natural Damage Assessment Process. Available online at: https://dec.alaska.gov/spar/perp/.../041207201_fact_nrda.pdf.
[25] Id.
[26] ECONorthwest. 2014. The Economic Importance of Alaska's Wildlife in 2011. Summary report to the Alaska Department of Fish and Game, Division of Wildlife Conservation, contract IHP-12-052. Portland, OR: ECONorthwest.

The distinction between direct, indirect and non-use values is illustrated in Table 2 below, adapted from the US National Research Council.[27] Direct use benefits of ecosystem services are those that involve some kind of physical interaction, such as the extraction of fish or freshwater for drinking from a river or most forms of recreation. Indirect use benefits are those that do not necessarily involve physical interaction but nonetheless represent a beneficial use; for example, the flood control benefits of wetlands that protect certain properties downstream even though the property owners who may benefit may not actually visit the wetlands providing this service.

**Table 2**
**Major Classification of Ecosystem Service Values and Some Examples**

| Use values | | Non-use values |
|---|---|---|
| *Direct* | *Indirect* | |
| Commercial and recreational fishing | Flood control | Existence value for imperiled species |
| Aquaculture | Water purification | Existence value for outstanding scenic areas |
| Hunting | Storm protection | Cultural heritage values for spiritual sites |
| Fuelwood and timber | Wildlife and fish habitat | Cultural heritage values for national landmarks |
| Recreation | Pollination of crops | Bequest values for aquifer protection |
| Genetic material | Carbon sequestration | Bequest values for farmland protection |

Non-use values (also referred to as passive use values) on the other hand, are intrinsic values people may hold for preservation of a resource even though they may not receive any direct or indirect benefits from it but they are willing to pay for such protection.[28] Non-use values include those associated with protecting biodiversity or natural landmarks for their own sake (existence values), preserving indigenous cultures (cultural heritage values) or the desire to pass on resources for future generations (bequest values).

The concept of total economic value (TEV) is used to describe the sum of all of these values – use, non-use, direct and indirect. TEV provides the most comprehensive measure of ecosystem service benefits and thus represents the "gold standard" when conducting valuation studies. For example, the TEV framework is now widely used in to identify the costs and benefits associated with protected areas.[29].

When original valuation studies are undertaken methods for quantifying these values are generally grouped into three major categories: revealed preference approaches, stated preference approaches, and cost-based approaches.[30] When budgets do not allow for original valuation

[27] National Research Council. 2005. Valuing Ecosystem Services. Towards Better Environmental Decision Making. Washington, DC: National Academies Press.
[28] Kaval, Pamela. 2010. A Summary of Ecosystem Service Valuation Methods and Recommendations for Future Studies. Department of Economics Working Paper in Economics 10/02. Hamilton, NZ: University of Waikato; Boardman, Anthony E., David H. Greenberg, Adrian R. Vining and David L. Weimer. 2001. Cost Benefit Analysis: Concepts and Practice. Upper Saddle River, NJ: Prentice Hall.
[29] ICEM. 2003a. "Protected areas as productive assets." In Lessons Learned from Global Experience. Review of Protected Areas and Development in the Four Countries of the Lower Mekong region. Indooroopilly, Queensland, Australia: International Centre for Environmental Management.
[30] De Groot, R.S., Wilson, M.A., and Boumans, R.M.J., 2002. "A typology for the classification, description, and valuation of ecosystem functions, goods, and services. Ecological Economics 41: 393-408.

studies, researchers use what is known as benefits transfer method. Below is a brief description of these groupings and methods within them.

5.1 Revealed preference approaches

Revealed preference methods of measuring ecosystem service values are based upon actual behavior in organized markets. In other words, value is revealed through direct market purchases of ecosystem goods or services or purchases of other goods or services whose prices are influenced by environmental quality. Specific techniques include:

- ***Market prices***: Valuations are directly obtained from what people actually pay for the ecosystem good or service in formal markets. Examples include the prices paid for fish, game, non-timber forest products, or recreational access.
- ***Travel cost***: Valuations of site-based amenities are implied by the travel costs people incur to enjoy them. For example, average purchases of fuel, food, and airline tickets to visit a particular natural area can be used to derive the value of a recreational visit.
- ***Hedonic pricing***: The value of a service is implied by what people will be willing to pay for the service through purchases in related markets, such as housing markets. A typical example of a situation amenable to use of hedonic pricing is the premium people are willing to pay for houses that are adjacent to parks and open space or which have spectacular scenic vistas. This price premium can be translated into a corresponding ecosystem service benefit per acre.
- ***Factor income***: Ecosystem service values are derived from their impact on yields and income from marketed products. For example, agricultural yields have been shown to be greater in fields that retain more biodiversity.[31] The increase in farmers' income is thus a signal of the underlying value of biodiversity.

5.2 Stated preference approaches

Stated preference methods of measuring non-market values use surveys or interviews to ask people directly about their willingness to pay for some good or service or to rank alternative management scenarios and ecological attributes. The surveys typically involve a choice about a hypothetical or proposed situation. A distinct advantage of stated preference methods is that they allow researchers and policy makers to target preferences for specific components of environmental changes, such as existence value.[32] A disadvantage is that survey results can be affected by strategic responses, or responses that are designed to influence the outcome of the research, rather than by honest responses. Researchers have also found that some people are not willing to trade money for a loss in environmental quality. Specific techniques include:

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[31] Shelley R. Rogers, David R. Tarpy, Hannah J. Burrack. 2014. "Bee species diversity enhances productivity and stability in a perennial crop." PLoS ONE 9 (5): e97307 DOI: 10.1371/journal.pone.0097307.

[32] Raheem, Nejem, John Talberth, Steve Colt, Erica Fleishman, Paula Swedeen, K.J. Boyle, M. Rudd, R.D. Lopez, Timothy O'Higgins, Chuck Willer and R. M. Boumans. 2006.The Economic Value of Coastal Ecosystems in California. Sacramento: California Ocean Protection Council.

- ***Contingent valuation***: People are directly asked their willingness to pay or accept compensation for some change in an ecosystem service or environmental quality. For example, the survey would ask respondents to state their maximum willingness to pay each year into a fund to acquire and protect habitat for an endangered species.
- ***Choice experiments***: Asking a series of questions about a respondent's relative preferences for various management strategies and associated ecological conditions. For example, respondents choose between various levels of water quality with different management strategies and associated costs of achieving those levels. There will typically be three or four alternative strategies with similar attributes (per question) presented.
- ***Conjoint analysis***: A variant of choice experiments where people are asked to rank (rather than choose one) ecological conditions created by various management strategies. For example, respondents would assign ranks to various scenarios for wetlands management that involve tradeoffs between flood control benefits and fishery yields.

5.3 Cost-based approaches

Cost-based methods use historical cost data or projections to quantify the costs society would incur if an ecosystem were lost or what it would take to replace an ecosystem service with a technological solution. There are three primary methods:

- ***Avoided cost:*** This method assigns values to ecosystem services based on costs that would be incurred in their absence. For example, forests, wetlands, and mangroves provide many flood control benefits. If they were lost, loss of life, property, and damage to infrastructure would increase.
- ***Replacement cost*****:** Valuing ecosystem services by calculating the cost of replacing them with technological solutions. For example, replacing natural fisheries with a system of hatcheries or wild pollinators with industrial bee hives.
- ***Restoration cost*****:** Restoration cost is a method used to calculate the cost of restoring an ecosystem to its natural state after it has experienced some environmental damage, such as an oil spill.[33] Or it involves calculating the cost of restoring ecosystems on damaged landscapes – such as promoting the natural regeneration of woodlands on areas that have been overgrazed by livestock. The cost of restoration is then used as a proxy for its ecosystem service values.

5.4 Benefits transfer

All of the methods discussed above are appropriate when analysts have the resources and time to complete original valuation studies. However, in many situations budgets for these studies or the requisite amount of time to complete them do not exist. In these situations, economists use a technique known as benefits transfer to use values obtained from original studies in other, similar settings.

For example, the annual value of fisheries provided by a particular river segment can be approximated by the value calculated for another nearby segment of similar length in the same

[33] Kaval, 2010, Note 28.

watershed. Or the per acre value of non-timber forest products in one area can be applied to the same forest type elsewhere in the region. In using the benefits transfer technique, great care must be given to ensure that (1) both sites are as identical as possible ecologically speaking; (2) there are no major differences in use patterns – i.e. one in an urban area, one in a rural area; (3) the same service is valued in both situations, and (4) values that are transferred in are calibrated to account for inflation, changes in exchange rates, purchasing power parity, and other economic and demographic factors that may influence the relevancy of the original valuation estimate to the new analysis.[34]

## 6.0 Duty to consider avoided costs of the Chuitna coal mine

Another economic effect important to ADNR's public interest determination is the effect of precluding "alternate uses of water that might be made within a reasonable time" if the application for reserved water is granted.[35] The economic concept here is the concept of opportunity costs. Opportunity costs are simply the net economic benefits forgone by choosing one use of a resource over another. In particular, "[t]he opportunity cost of using an input to implement a policy is its value in its best alternative use."[36]

Opportunity costs can be positive (and thus registered as a cost of the decision) if the precluded uses generate more economic benefits than costs, or negative if the precluded uses generate more economic costs than benefits. In the latter situation, preclusion leads to cost savings, a form of economic benefit commonly referred to as "avoided costs." In a nutshell, "[c]osts avoided represent what you don't have to pay because of the action you have taken."[37] Importantly, "a negative opportunity cost implies that the action taken is better than all alternatives."[38]

In this case, preclusion of the Chuitna coal mine by a grant of instream flow rights to CCC will avoid the substantial litany of costs enumerated in CSE's 2011 analysis of net public benefits associated with mine development.[39] In that analysis, we determined that taking all known public and private costs into account, developing the mine would represent a net economic loss to the public of $57.23 billion to $75.27 billion depending on the price scenario for coal purchased from the mine on Asian markets and other value assumptions. These avoided costs are discussed in more detail later in this report.

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[34] Johnston, R,J. and R.S. Rosenberger. 2010. "Methods, trends and controversies in contemporary benefit transfer." Journal of Economic Surveys 24(3): 479-510; Economics for the Environment Consultancy (Eftec). 2009. Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal. London: Department for Environment, Food, and Rural Affairs.
[35] AS 46.15.080(b).
[36] Boardman et al., 2001, Note 6.
[37] US Environmental Protection Agency (EPA) and US Army Corps of Engineers (ACOE). 2014. Economic Analysis of Proposed Revised Definition of Waters of the United States. Washington, DC: EPA and ACOE.
[38] Caplan, Dennis. 2014. Management Accounting: Concepts and Techniques. Part 2: Micro-economic foundations of management accounting. Available online at: http://classes.bus.oregonstate.edu/fall-06/ba422/Management%20Accounting%20Chapter%203.htm.
[39] Talberth, John and Evan Branosky. 2011. Net Public Benefits of the Chuitna Coal Project. A Preliminary Assessment. Santa Fe, NM: Center for Sustainable Economy.

## 7.0 A critique of the DNR valuation

Despite the clear linkages between ADNR's public interest standard and the framework offered by ecosystem services, the agency concentrated on one aspect of a single service – the ex-vessel value of the presumed adult coho population. To meet its obligations to represent the economic interests of all Alaskans, ADNR should quantify the full range of ecosystem service values associated with the Middle Creek watershed using readily available information and methods at the agency's disposal. The following section summarizes the problems with ADNR's limited analysis to date.

### 7.1 Exclusion of values for most goods and services

The analysis excludes the vast majority of economic value associated with protection of Middle Creek. To reiterate: the ADNR valuation exercise concentrated on just a single provisioning service supported by Middle Creek – provision of coho salmon – and excluded valuation of all of the other goods and services associated with the wide range of uses described in Section 4.1, above. These include the value of all other direct uses of the watershed such fishing for species other than coho, recreation, hunting, and subsistence as well as indirect and non-use values such as carbon sequestration, clean water, and passive use values for pristine environments. Values can be assigned to all of these goods and services using one or more of the standard methods to do so described in Section 5.

For example, the value of all fish, game, birds and wild plants harvested for subsistence can be assigned a value based on the replacement cost method (which asks what the value of market substitutes are) in line with regular valuation assessments conducted by the Alaska Department of Fish and Game, Division of Subsistence. Using a replacement cost range of $4.00 to $8.00 per pound the statewide value of subsistence harvests in 2012 was estimated to range between $201 to $402 million.[40] As previously discussed, passive use values for wild salmon in Upper Cook inlet have been estimated to be $3.98 (2010 dollars) per fish.[41] The value of all ecosystem services can be estimated using the benefits transfer technique to apply per-acre values to each of Middle Creek's vegetation communities (see below). Thus far, ADNR has focused on a single ecosystem service value and has ignored others that can easily be quantified.

### 7.2 Valuation of the coho catch is based on the wrong method

For the single ecosystem service ADNR valued, the valuation method is wrong. Assume, for now, that the data on the annual survival rate (246 to 1,789 coho) is correct and that all of the annual catch (123 to 781) is associated with commercial or subsistence fishing and that there are no other fish caught of value in the stream. In this case, the choice of ex-vessel price as a measure of value is erroneous. The correct method for valuing commercial and subsistence goods is to apply market prices because these reflect the true societal willingness to pay for the goods or the true

[40] Division of Subsistence. 2014. Subsistence in Alaska: A Year 2012 Update. Anchorage, AK: Alaska Department of Fish and Game.
[41] Helvoigt et al., 2010, Note 19.

replacement value of those caught for subsistence.[42] For coho in the Anchorage market, prices right now are running right now about $10 per pound. The $0.91 per pound value used by ANDR is thus a gross underestimate.

But all of the catch derived from Middle Creek is not commercial or subsistence. Sport fishing likely makes up a significant share of the value of the fishery supported by Middle Creek. This is an important distinction because the method for valuation of sport fishing is much different. As noted by Bingham (2015), "[t]he value to sport anglers of a fish harvested in the recreational fishery is not directly comparable to the value in the commercial fisheries."[43] It is based on the consumer surplus or net economic value (NEV) of fishing trips. NEV is simply the difference between what anglers are willing to spend on a fishing trip over and above what they do pay. The NEV of sportfishing in Alaska has been well studied.

One of the most rigorous and often-cited studies estimated "NEVs from $817 per nonresident trip targeting salmon in remote sites to $34 per resident trip for road-accessible stocked waters."[44] The upper bound translates into $1,220 in today's dollars, and should be used in the evaluation of Middle Creek's sport fishery value.

The ADNR method also fails to use the correct analysis period. The choice of a 25-year analysis period is wrong because the damage to the Middle Creek fishery will extend well beyond the life of the mine. There are no precedents for replacing a salmon fishery once mined, so the safe assumption is to model the loss well into the future. At minimum, the analysis period should be set at 50 years.[45]

Finally, there is also substantial evidence that ADNR presented biased estimates of both the coho survival rate and corresponding catch. As noted by Bingham (2015), previous surveys estimated a survival rate of 1,983 to 2,313 adult coho per year and noted that these were likely conservative.[46] If the same catch percentages hold as in the ADNR memo, this would translate into a catch of roughly 1,000. This makes a big difference to the estimate of value, as shown below.

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[42] "*Market price-based approaches* are most often used to obtain the value of provisioning services, since the commodities produced by provisioning services are often sold on, e.g., agricultural markets. In well-functioning markets preferences and marginal cost of production are reflected in a market price, which implies that these can be taken as accurate information on the value of commodities. The price of a commodity times the marginal product of the ecosystem service is an indicator of the value of the service, consequently, market prices can also be good indicators of the value of the ecosystem service that is being studied" – from The Economics of Ecosystems and Biodiversity (TEEB): The Economic and Ecological Foundations. Available online at: http://www.teebweb.org/our-publications/teeb-study-reports/ecological-and-economic-foundations/.

[43] Bingham, Allen. 2015. Review of Alaska Department of Natural Resources Economic Valuation of Middle Creek (Stream 2003). Anchorage, AK: Bingham Statistical Consulting.

[44] Duffield, J.; Merritt, P.; Neher, C. 2002. Valuation and policy in Alaskan sport fisheries. In: Pitcher, T.; Hollingworth, C., eds. Recreational fisheries: ecological, economic and social evaluation. Bangor, Wales, UK: Blackwell Science: 156–185.

[45] See, e.g. Talberth and Branosky, 2011, Note 39.

[46] Bingham, 2015, Note 43.

7.3 Failure to quantify the avoided costs of the Chuitna coal mine

This duty was discussed in Section 6, above. Preclusion of the Chuitna coal mine by a grant of instream flow rights to CCC will avoid the substantial litany of costs enumerated in CSE's 2004 analysis of net public benefits associated with mine development. Below, we discuss the likely magnitude of these costs in today's dollars.

## 8.0 Likely magnitude of missing values

ADNR has access to peer reviewed methods and sources of information to correct these deficiencies. By doing so, the true value of granting CCC's instream flow application will become apparent and reflect values that are astronomically greater than the limited analyses completed to date on just one small sliver of economic value. The following figures are indicative of the range of values that Middle Creek's ecosystems provide in their natural state.

8.1 Value of wild coho, market replacement prices: **$3.3 million to $3.9 million.**

As noted above, ADNR incorrectly uses the exvessel value rather than market price and so underestimates the true worth of surviving adult coho by a factor of 10 or more. Moreover, ADNR uses a biased estimate of the adult survival rate and an arbitrarily short analysis period of 25 years. Using the current market price (paid by households) of $10 per pound, a survival rate of 1,983 to 2,313 fish[47], the ADNR value of 6.52 pounds per fish and an analysis period of 50 years translates into a present value worth of $3.3 million to $3.8 million. ADNR's estimate was $36,470 to $265,219.

8.2 Value of wild coho, passive use: **$222,967 to $260,071.**

As discussed previously Helvoigt et al. (2010) estimated Alaska's annual marginal non-use willingness to pay for a Upper Cook Inlet salmon to be $3.98. This reflects the intrinsic or passive use values Alaskan's place on preserving wild fish and their habitat. This translates into a value of $4.37 in today's dollars. Over a 50-year period this equates to a value of $222,967 to $260,071. This value is over and above the value of these fish in terms of their value to consumers.

8.3 Net economic value of sport fishing: **$10.4 million to $12.1 million.**

An updated per-trip NEV for salmon at remote locations based on Duffield et al. (2002) is equivalent to $1,220 in today's dollars. That same study estimated salmon catch per trip ranging from 3 to 10, with the lower values associated with the most remote locations. If we assume that (1) roughly half the catch is sport fishing related; (2) catch per trip is on the low end, or 3 salmon and (3) model the benefits as before with a 3% discount rate and a 50-year time horizon, the value of coho sportfishing ranges from $10,374,498 to $12,100,965. This is probably conservative, as it does not account for sportfishing trips to take other species. To more

[47] Again, these figures are discussed in Bingham (2015) and are indicative of a more reasonable estimate than those contained in ADNR's analysis. We use these in subsequent calculations but recognize they are not definitive.

accurately estimate even this one resource, ADNR could determine the proportion of the catch that is sport related and value it in accordance with standard NEV methods using NEV data from around the region.

8.4 Ecosystem service values based on Earth Economics study: **$1.4 billion to $3.5 billion.**

By granting CCC's application development of the Chuitna coal mine will be precluded. This will not only benefit Alaskans by protecting the immediate stream corridor along Middle Creek but the entire watershed of Middle Creek since it is slated for development and will otherwise be damaged by the mine and associated infrastructure. Thus, ADNR's analysis of benefits of the application must include an analysis of the ecosystem service benefits that are generated by all lands and waters in the 9,126-acre watershed.

Fortunately, there has been a recent and comprehensive study nearby that can be used as a basis. This was a study prepared by Earth Economics for the 15 million acre Matanuska-Susitna watershed. Earth Economics found that the value of 13 ecosystem services produced by 10 land cover types ranges from $20 to $51 billion in economic value each year.[48] This translates into an average value of $1,702 to $4,284 per acre per year across the basin.

The Earth Economics study used the figures reported in Table 3 (updated to 2015 values) as a basis for valuation of each of the land cover types that are also present in the Middle Creek watershed. They range from a low of $90 per acre for mixed forest (including spruce-birch) under the low price scenario to a high of $36,106 for wetlands under the high price scenario. These compare well with other values reported in the literature, and in fact in many cases are conservative.[49]

Applying the per-acre values in Table 3 to the vegetation profile from Table 1 and then calculating the present value over 50 years yields a benefit estimate of $1,424,658,380 for the low case and $3,452,821,042 for the high case. This represents an annual value of between $55.4 and $134.2 million. Not all of the ecosystem services considered by Earth Economics may be present for ecosystems in the Middle Creek watershed, nonetheless, the magnitude of these benefit estimates underscores the imperative for ADNR to take ecosystem service valuation into account. Otherwise, ADNR will ignore the vast majority of benefits from a grant of the CCC application.

[48] Kocian, Maya, David Batker and Angela Fletcher. 2013. The Natural Economy of Alaska's Matanuska-Susitna Basin. Tacoma, WA: Earth Economics.

[49] One recent nationwide study, for example, found that the range of ecosystem service benefits from wetland mitigation to be in the order of $5,000 to $70,000 per year. See: Adusumilli, Naveen. 2015. "Valuation of ecosystem services from wetlands mitigation in the United States." Land 4(1): 182-196; doi: 10.3390/land4010182. These values are for constructed wetlands. Natural wetland values are generally much higher and so the EE values are conservative.

**Table 3**
**Ecosystem Service Values for the Middle Creek (Stream 2003) Watershed***
(Totals represent present value over 50 years at a 3% discount rate)

| Land cover | Acres | $/acre low | $/acre high | PV low | PV high |
|---|---|---|---|---|---|
| Mixed forest | 3,292.76 | $89.88 | $340.26 | $7,614,816 | $28,827,517 |
| Coniferous forest | 72.64 | $98.44 | $379.85 | $183,990 | $709,961 |
| Deciduous forest | 59.71 | $80.25 | $299.60 | $123,281 | $460,249 |
| Shrub/scrub | 954.29 | $206.51 | $274.99 | $5,070,599 | $6,752,041 |
| Riparian buffer | 451.00 | $391.62 | $18,768.87 | $4,544,407 | $217,796,287 |
| River | 37.00 | $468.66 | $11,798.89 | $446,165 | $11,232,558 |
| Meadows | 833.89 | $19.26 | $255.73 | $413,238 | $5,486,878 |
| Wetlands | 3,424.71 | $15,959.05 | $36,106.08 | $1,406,261,885 | $3,181,555,551 |
| | | | Totals: | $1,424,658,380 | $3,452,821,042 |

**Source: Based on updated per-acre values reported in Earth Economics (2010)*

8.5 Instream flow benefits: **$183.4 million to $436.6 million.**

Another way economists have estimated ecosystem service values in particular watersheds is to concentrate on the benefits provided by river flows – most importantly for recreation, fishing, and other direct uses including domestic, agricultural, or industrial water supply. Such studies also capture the passive use values for maintaining river flows that may exist in a larger population regardless of actual use of the river.

This is a more limited approach than ecosystem service valuation for entire watersheds, but is nonetheless informative. It requires calculating values on a cubic feet per second (Cfs) or acre-foot basis for multiple flow benefits including recreation, wildlife, fish, cultural and passive use.

In a study of the benefits of instream flow protection in the Poudre River in Colorado, Loomis (2008) followed federal benefit-cost procedures by measuring economic benefits as the amount that households would pay to maintain the current flows.[50] Using federally recommended dichotomous choice contingent valuation methodology, the median willingness to pay (WTP) of Fort Collins residents was found to be $234 per year. This represents annual value of water for instream flow of $171 to $255 per acre-foot during the April to September 6th time period. Another study addressing flow through the Glen Canyon Dam was conducted nationally through a contingent valuation survey and found a mean willingness to pay of $506.92 per acre-foot.[51] There have been few instream flow studies in Alaska, but there is no reason to assume that these broad benefits associated with instream flow in Middle Creek and the Chuitna River would not apply and be within a comparable range.

[50] Loomis, John. 2008. Estimating the Economic Benefits of Maintaining Peak Instream Flows in the Poudre River through Fort Collins, Colorado. Fort Collins, CO: Department of Agricultural and Resource Economics.
[51] Welsh, M., R. Bishop, M. Phillips, and R. Baumgartner. 1997. Glen Canyon Environmental Studies Non-Use Value Final Study Summary Report.

To illustrate the importance of taking instream flow values into account, we can use the Loomis (2008) and Welsh (1997) estimates as lower and upper bounds. Updating to current dollars yields $213.14 per acre-foot as the low value and $564.37 as the upper end. Applying these to the annual acre-foot equivalent[52] being adjudicated in the CCC application and then taking the present value of these benefits over 50 years yields the benefit estimates shown in Table 4: $183,443,288 to $436,577,079. ADNR's evaluation of the benefits of CCC's reservation should include at least some marginal benefit figure for each acre-foot reserved based on values reported in the published literature.

**Table 4**
**Instream Flow Values for the Middle Creek (Stream 2003) Watershed***
(Totals represent present value over 50 years at a 3% discount rate)

| Reach | Mean Cfs | Acre-feet/yr | $/acre-ft low | $/acre-ft high | PV low | PV high |
|---|---|---|---|---|---|---|
| Lower | 25.71 | 18,626 | $237.14 | $564.37 | $113,647,586 | $270,470,137 |
| Middle | 9.00 | 6,520 | $237.14 | $564.37 | $39,782,147 | $94,677,617 |
| Main | 6.79 | 4,919 | $237.14 | $564.37 | $30,013,555 | $71,429,325 |
| | | | | Totals: | $183,443,288 | $436,577,079 |

**Source: Based on updated per-acre/ft values reported in Loomis (2008) and Welsh et al. (1997)*

8.6 Avoided costs of the Chuitna coal mine: **$58.78 billion to $78.01 billion.**

In 2011 CSE conducted a preliminary net public benefits (NBP) evaluation of the Chuitna coal mine taking all public and private benefits and costs into account. The NBP analysis was conducted in accordance with standard federal procedures and yielded estimates of the project's net present value and benefit cost ratio for four price scenarios and two delivered coal price scenarios to Asian markets. The analysis indicated that costs will exceed benefits by a large margin representing a net present value loss of between $57.23 and $75.27 billion over a 50 year analysis period. Social costs were determined to range between 193% and 604% of market prices, a finding that corroborates the range published in the academic literature. More recent market information suggests that the loss will be closer to the top end of this range since market prices are falling fast. As noted by the New York Times, "[m]arket forces have accomplished in just a few years what environmentalists and social advocates have struggled for decades to achieve. Coal prices have plunged about 70 percent in the last four years."[53] Another recent review of Asian coal markets and price structures concludes "[t]he Chuitna coal project would

[52] The cubic-feet reservation per month figures reported by ADNR can be converted to annual acre-feet equivalents by a number of useful online tools. We used the tool available here: http://www.convertunits.com/from/%28cubic+feet%29+per+second/to/%28acre+feet%29+per+year.
[53] Stewart, James B. 2015. King Coal, Long Besieged, is Deposed by the Market. New York Times, August 6th, 2015. Available online at: http://www.nytimes.com/2015/08/07/business/energy-environment/coal-industry-wobbles-as-market-forces-slug-away.html.

serve little purpose in this shrinking [coal] market over the next several decades. There is no need for the mine and no price structure to support it."[54]

The three most significant social costs identified included carbon emissions damage ($17.26 billion), air pollution damage ($53.09 billion) and loss of ecosystem services ($2.08 billion). Ecosystem service damages were estimated before the Earth Economics study was published, but are nonetheless remarkably consistent with the values implied by that study, falling squarely within the rage of benefits reported in Table 3 ($1.4 to $3.5 billion).[55]

Including damages to ecosystem services in this avoided cost calculation, however, would amount to double counting if ecosystem service benefits are also considered, so a more valid assessment of avoided costs from the mine would exclude them. But if the avoided cost calculation rests on its own, then ecosystem service damages should be considered. For this preliminary assessment, we exclude ecosystem service damages (since we report ecosystem service benefits in Table 3) and update the remaining avoided cost figures to current values. This yields an avoided cost estimate of between $58.78 billion and $78.01 billion, which represents the enormous economic value to the public of leaving the coal beds untouched.

**Summary and conclusions**

In making a public interest determination associated with Chuitna Citizens Council's application to reserve instream flow in Middle Creek (Stream 2003) ADNR has not ensured that all significant costs and benefits are considered. In this case, the cursory assessment of just one small type of benefit – the market value of coho – represents a small amount compared to the vast ecosystem service values that the 9,126-acre Middle Creek watershed generates for Alaskans on an annual basis.

These ecosystem service values include those associated with a wide range of direct uses such as hunting, fishing, and subsistence foods as well as passive use values for maintaining Alaska's pristine watersheds. Together, they are likely to generate between $55.4 million to $134.2 million in value each year. ADNR has, at its disposal, all of the methods and sources of information needed to produce credible estimates of ecosystem service benefits for the Middle Creek watershed and break those benefit estimates out into sub categories of interest such as those associated with coho, sportfishing and instream flow as demonstrated above.

ADNR also has a duty to consider the significant avoided costs associated with a grant of CCC's application. Should that application be granted, the public would be spared the enormous social and environmental costs associated with development of the Chuitna coal mine – avoided costs that are measured in the tens of billions.

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[54] Letter from Tom Sanzillo, Director of Finance, Institute for Energy Economics and Financial Analysis, to Kimberly Sager, ADNR (Apr. 6, 2015) (on file with ADNR).

[55] The CSE (2011) estimates were based on damages, and the Table 3 (and Earth Economics) estimates based on benefits, but the two should be similar since the value of damages from the mine should be roughly equal to the annual ecosystem service benefits of keeping Middle Creek and the rest of the project area intact.

ADNR has failed to consider the immense ecosystem service values of the Middle Creek watershed and the avoided costs of the Chuitna coal mine in its public interest evaluation of CCC's application.